This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

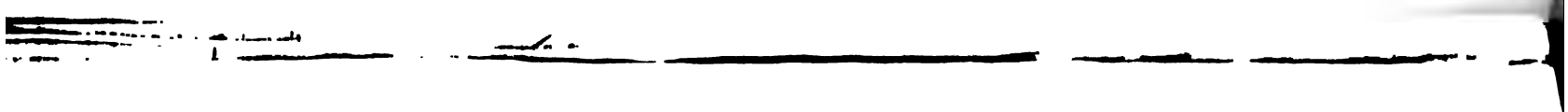
About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

HARVARD UNIVERSITY

LIBRARY OF THE

Department of Mining
and Metallurgy



THE

SCHOOL OF MINES

QUARTERLY.

VOL. VIII.

OCTOBER, 1886, TO JULY, 1887.

COLUMBIA COLLEGE,

NEW YORK CITY.

1887

Per 27

MAY 19 1908

Mining & Met. Laboratory

EDITORS.

J. K. REES, J. B. MACKINTOSH, A. J. MOSES,
J. L. GREENLEAF, H. PARSONS, E. A. CONGDON.

J. L. GREENLEAF, *Managing Editor.*

A. J. MOSES, *Business Manager.*

ASSOCIATE EDITORS.

F. A. P. BARNARD, J. S. NEWBERRY, T. EGLESTON, W. P. TROWBRIDGE, H. S. MUNROE,
F. R. HUTTON, ELWYN WALLER, P. DE P. RICKETTS, M. W. ILES, R. D. IRVING,
H. B. CORNWALL, P. T. AUSTEN, C. M. ROLKER, J. A. CHURCH, W. B.
POTTER, S. A. REED, W. B. DEVEREUX, J. M. ADAMS.
H. M. WILSON, J. C. F. RANDOLPH.

CONTENTS OF VOL. VIII.

ORIGINAL PAPERS.

ACTION of Hydrofluoric Acid on Silica and Silicates..... 115
ACTION of Sulphurous Anhydride on Benzine..... 253
ADAMS, J. M., Concentration of Gold and Silver Ores on the Pacific Coast..... 336
BARNARD, F. A. P., Elective Studies..... 20
——— Letter to Graduates..... 164
BAYS MOUNTAINS, TENNESSEE, Topography and Structure..... 242
BLOW-PIPE ANALYSIS, Scheme for..... 359
BOAT RACING, Inter-Collegiate..... 368
BROWN, W. L., Notes on the Analysis of Chrome Paints..... 81
BRUGMAN, W. F., Influence of Copper on the Estimation of Sulphur..... 74
BUTLER, W. P., The Durant-Emma Case..... 235
CHROME PAINTS, Notes on the Analysis of..... 81
COLBY, C. E., On the Action of Sulphurous Anhydride on Benzine..... 253
COLOR CONTRAST..... 307
COLUMBIA COLLEGE CENTENNIAL..... 257
COMPARISON of the Delicacy of Certain Qualitative Tests..... 366
CONCENTRATED ROLLING LOADS..... 317
CONCENTRATION of Gold and Silver Ore on the Pacific Coast... 336
DRIFT-MINING..... 204, 289
DURANT-EMMA CASE..... 235
EARTHQUAKES..... 1
EGLESTON, T., Drift-Mining..... 204, 289
——— The Mendheim Continuous Gas-Furnace for Burning Fire-Brick and Porcelain..... 34
——— Treatment of Gold in the Arrastra..... 125
ELECTIVE STUDIES..... 20
FRANKLINITE and some Associated Minerals..... 148
GEOLOGICAL NOTES..... 327
GOLD IN THE ARRASTRA..... 125
GOLD MILLS, Some Old..... 61
GREAT TELESCOPES of the World..... 135

HIDDEN, W. E., On a Meteoric Iron from South Carolina..... 31
HILDRETH, R. W., Concentrated Rolling Loads 317
HOLBROOK, F. N., Some Old Gold Mills..... 61
HUTTON, F. R., Notes on Railway Block Signals..... 54
IN CAMP on a Preliminary Survey..... 75
INFLUENCE OF COPPER on the Estimation of Sulphur..... 74
LINE OF ORIGIN of the Charleston Earthquake..... 64
MACKINTOSH, J. B., On the Action of Hydrofluoric Acid on Silica and Silicates..... 115
——— Separation of Nickel and Cobalt from Iron, 335
McLOUGHLIN, C. S., Action of Sulphurous Anhydride on Benzine 253
MENDHEIM CONTINUOUS GAS-FURNACE for Burning Fire-Brick and Porcelain..... 34
MERRILL, F. J. H., Geological Literature, Index of..... 172, 285, 375
METEORIC IRON from South Carolina 31
MOSES, A. J., Scheme for Blow-Pipe Analysis..... ... 359
NEWBERRY, J. S., Earthquakes..... 1
——— Geological Notes..... 327
OUR Grandest Mountain and Deepest Forest..... 152
RAILWAY BLOCK SIGNALS..... 54
REES, J. K., The Great Telescopes of the World..... 135
REULEAUX, PROF., On New Features in Teledynamic Transmitters.....93, 220
ROOD, O. N., Color Contrast 307
SCHEME for Blowpipe Analysis..... 359
SEPARATION of Nickel and Cobalt from Iron..... 335
STAREK, EMIL, Line of Origin of the Charleston Earthquake..... 64
STONE, GEORGE C., Analyses of Franklinite and Some Associated Minerals..... 148
STUART, W. H., in Camp on a Preliminary Survey, ... 75
SUB-SURFACE WATER SUPPLIES..... 191
TELEDYNAMIC TRANSMITTERS, New Features in..... 93, 220
TROWBRIDGE, W. P., Inter-Collegiate Boat Racing 368
——— Sub-Surface Water Supplies..... 191
WELLS, J. S. C., Comparison of the Delicacy of Certain Qualitative Tests..... 366
WILLIS, BAILEY, Our Grandest Mountain and Deepest Forest... 152
——— Topography and Structure in the Bays Mountains, Tennessee 242

PROFESSIONAL NOTES AND ABSTRACTS.

AMERICAN METROLOGICAL SOCIETY 176
BURLINGTON BRAKE TESTS..... 376
CANTILEVER BRIDGES..... 379
COST of Labor in Ceylon..... 184
THE CRYSTALLINE Structure of Iron Meteorites..... 90
FERRUGINOUS SCHISTS and Iron Ores of the Lake Superior Region..... 188
FORTH BRIDGE..... 184
GENESIS OF THE DIAMOND 188
IRON *vs.* STONE BRIDGES..... 186
THE LICK OBSERVATORY..... 180
LIQUID OXYGEN, Nitrogen, and Carbonic Oxide..... 174
MILD STEEL *vs.* IRON..... 185
RESISTANCE of Railway Trains..... 286
THE "SIPHON TAP CASE"..... 175
THE ST. LAWRENCE BRIDGE..... 184
VOLUMETRIC Determination of Sulphuric Acid without Standard Solutions..... 187
WOODEN DAMS..... 186
WORKING STRESS ON RIVETS..... 185

BOOK REVIEWS.

CATALOGUE OF MINERALS (Albert H. Chester)..... 88
ELEMENTARY TREATISE on Determinants (William G. Peck) 288
ELEMENTARY PHYSICS (Balfour Stewart, and H. Gee)..... 383
MECHANICS OF MACHINERY (Alex. B. W. Kennedy)..... 382
PRINCIPLES AND METHODS of Soil Analysis (Edgar Richards).... 89
SIXTH ANNUAL REPORT of State Mineralogist of California..... 288
TRACK, A Complete Manual of Maintenance of Way (W. B. Parsons, Jr.)..... 87
THEORY AND PRACTICE of Surveying (J. B. Johnson, C.E.)..... 88

MISCELLANEOUS.

ADDITIONS TO THE COLUMBIA COLLEGE LIBRARY in the Department of Natural Science, Useful and Fine Arts, October, 1886 to July, 1887.....167, 282, 373
CURRENT LITERATURE Relating to North American (F. J. H. Merrill).....172, 285, 375

HARVARD UNIVERSITY

LIBRARY OF THE

Department of Mining
and Metallurgy

THE

SCHOOL OF MINES

QUARTERLY.

VOL. VIII.

OCTOBER, 1886, TO JULY, 1887.

COLUMBIA COLLEGE,

NEW YORK CITY.

1887

sheets of lava, hot springs abound there, and it is evident that the subterranean fires are not yet extinguished. A boring on the flanks of Mt. Etna would be a still more striking exception to the rule of one degree for every 50 feet, and would be equally legitimate evidence against it.

Excluding these abnormal cases, which really have no bearing on the question, the irregularities in the rate of increase in temperature are not greater than those which might be caused by differences in the conductivity of the rocks passed through. The deep wells of Sperenberg and Schladenbach—which were bored in part to test this question, and have been the most carefully observed of any—have given the most convincing evidence of the truth of the theory of intense internal heat.* The case cited by Professor Judd (*Volcanoes*, p. 341), "a deep well in Buda-Pesth, in which there was a decline of temperature below 3000 feet," is probably a mistake or a fraud. The same thing happened at the deep well at St. Louis, in which the temperature increased regularly to the depth of 3200 feet, where it was 107° Fahr. Below that the contractor reported the temperature declining, *because the directors were about to stop the work, partly on account of the warmth of the water!* To prevent exposure of the fraud iron rails were dropped into the well.

It may then be considered as established that all over the earth's surface, except in volcanic districts, the temperature increases about one degree Fahr. for every 50 feet descent. It is evident that should this rate of increase continue the temperature at the depth of 50 miles would be sufficient to melt all known substances, and the first conclusion from the observations of tempera-

* Some of the temperatures in the Schladenbach well are as follows:

Depth in Metres.	Temp. Fahr.	Reaum.
1266	113.5°	36.2°
1296	115.°	36.9°
1326	116.8°	37.7°
1356	119.3°	38.8°
1386	121.3°	39.7°
1416	122.9°	40.4°
1506	127.2°	42.3°
1566	128.3°	42.8°
1596	130.1°	43.6°
1626	131.°	44.°

ture in mines and wells was that the solid portion or crust of the earth could not be more than 40 or 50 miles in thickness, and it was proclaimed that we were living on a film of solid matter, floating on a sea of molten rock. The comparative stability, however, of the earth's figure—the little effect produced by the attraction of the sun and moon—have led to the conclusion that the earth's crust is thicker than this, and it has been suggested that while the accuracy of the observations on the increase of temperature to the depth of one mile cannot be questioned, it is possible that the rate of increase to that depth is not constant below; that the increment may diminish, and therefore, the temperature of fusion may only be reached at a greater depth than has been supposed.

It has also been shown that the melting point of many substances is raised by pressure, and therefore, that the enormous weight of the overlying rocks, equivalent to 5,280,000 lbs. to the square foot for every mile, may hold in coerced rigidity a considerable zone of the earth's mass composed of materials that would melt and flow on the surface at a much lower temperature than that which they now endure in a solid form. Accepting, then, the conditions imposed on the old theory of the state of the interior of the earth by pressure and the possible diminution of the increment of temperature, we may suppose that the solid crust is considerably thicker than was formerly supposed. That it is relatively thin, however, is indicated by facts which will be cited further on.

The increase in temperature observed in mines and deep borings means that the heat of the interior of the earth is constantly escaping to the surface, where it is radiated into space. If the outer crust were a perfect non-conductor the materials within it would always maintain a condition of thermal equilibrium throughout. It is thus evident that the process of refrigeration is progressive, and from the time when the first film of solid matter dimmed the brightness of the "glittering globe of liquid fire" the crust formed at the surface has been constantly increasing in thickness, while by the loss of heat, which is an expansive force antagonistic to gravity, the volume of the earth has been as constantly diminishing. But since the outer crust has lost its inherent heat and has become solid it no longer shrinks, though the loss of volume goes on incessantly in the intensely heated, but gradually cooling interior. As the nucleus contracts the solid crust cannot accommodate itself moment by moment to the loss of volume, for it resists by its

rigidity and is brought into a state of strain. This is relieved from time to time, whenever it passes the resistance of the materials composing the crust, by a crushing together and displacement of the surface rocks. These are *faulted* or *folded;* that is are either thrown into great waves by lateral pressure, or the arches are broken and fissures are produced at right angles to the line of thrust. The rocks forming the sides of these fissures slide on each other, forming what geologists call *faults*, in which the "throw" or displacement sometimes amounts to many thousand feet. Earthquakes, mountain chains and volcanic eruptions may all be considered as consequences of this readjustment. Mountain chains are great lines of fracture in the earth's crust along which rocks before nearly horizontal are raised into ridges by lateral pressure. They have been compared, not inaptly, to the wrinkles formed in the rind of a fruit when it loses its volume by drying. Every mountain chain shows many folds and faults; in the Alleghanies the folds are noticed by every traveller, and few better examples of folded strata are seen anywhere than those which border the gorge which cuts through the ridges from Cumberland to Frostburg, Maryland. The faults are less conspicuous and would hardly be detected except by a geologist, but they are very numerous, and in some of them the displacement is more than 20,000 feet. The Wasatch Mountains in Utah—one of the boldest ranges on the continent—owe their relief mainly to a fault which runs nearly north and south through the middle of the Territory. The country west of this fault is thrown down and that on the east raised to form a wall 5000 to 7000 feet high.

It is evident that the folds and fractures seen in every mountain belt could not have taken place without great disturbance of the surrounding country. And as they have been formed, not all at once, but each by itself, and each one by many paroxysms, an almost infinite series of earthquakes is recorded in the structure of every mountain chain. A large number of earthquakes of modern times have been attended by changes of topography which have remained as evidences of the displacements which caused the vibrations. Sometimes a line of coast was raised above the ocean level, sometimes mountains or cliffs split and fell, sometimes fissures and faults were formed many miles in length.

Another thing about mountain chains is not so generally known as that they are lines or belts of folded and fractured rocks; and that

is that they are the products not of moments or even years but of ages. The lines of fracture which are marked by mountain chains are ever, after the first disruption, lines of weakness, where the resistance to lateral pressure is diminished, and where the strain of large unbroken areas is relieved from time to time by displacements, necessarily attended by earthquakes. I have sometimes compared them to hinges on which the great tables of the earth's crust turn with constantly changing angles. Generally mountain chains may be said to grow by the constant or paroxysmal elevation of their arches, the increase in the throw of their faults. This growth would be much more apparent than it is if it were not that the mountain chains receive a far greater precipitation of moisture than the lowlands, and erosion, which is the opposing force to elevation, counteracts its effects. The East Indian geologists estimate that in the Himalayas the process of elevation is going on constantly and that it is at least equal to the loss from denudation.

The application of all that has gone before to the Charleston earthquake is simply this: that we learn from the facts cited that displacements are constantly taking place in the crust of the earth the world over, and as these affect rigid and resistant masses of rock they are produced *per saltum*, that is in paroxysms. The strain accumulating until it overcomes the resistance is relieved in one or many efforts, each of which is attended by an earthquake vibration of greater or less force. The country bordering a disturbed belt is sure to feel the effects of subterranean movements more frequently than plains and plateaus remote from mountains. Every year we hear of local disturbances in the Southern Alleghanies, and Bald Mountain has been the scene of so many that it has come to be looked upon with awe and apprehension by the people in the vicinity. So along up the Atlantic slope of the Alleghanies there have been many earthquakes since the country was occupied by the whites. Not a year passes that we do not hear of several in New England, the Middle or Southern States. As the population increases, the number of observers is multiplied and the number of structures liable to damage constantly added to; so that such phenomena now attract more attention and cause greater destruction than formerly. In New England the best record of earthquakes has been kept, and if any one will look over a file of newspapers published at Boston or Hartford he will find that within the last century a very large number of earthquake shocks

or vibrations are noticed. Earlier than that we must depend upon town records or private correspondence. From these we learn that in 1727 the country about Newburyport, Mass., was shaken up, very much as Charleston has recently been, but in that region there were then but few buildings and those of wood; so that the damage was comparatively small.*

Two years ago New York City suffered an earthquake shock, but fortunately not a severe one. It occurred about two o'clock Sunday afternoon, the 10th of August. I was sitting alone in my room in the College, where all was perfectly still; suddenly I heard a heavy rumbling sound like that of a passing loaded wagon ten times magnified. At the same time the building began to vibrate, the windows rattled and some light objects were disturbed and fell to the floor. I was sensible of a tremor that not only jarred but swayed my body and caused my book to vibrate and swing in my hand. I recognized the nature of the phenomena at once, observed the time and made a note of it. Subsequently going into the geological cabinet I found palpable evidence of the force of the vibrations. In a case occupied by specimens of marble, many of which were set on edge against the back of the case, all such were thrown down and some were broken. As the back of the case was toward the north, this proved that some of the vibrations were from that direction. This earthquake was noticed by a number of observers, and their testimony showed that the area affected was, as usual, elliptical in outline, and extended from Washington, D. C., to Portsmouth, Me., and from Harrisburg, Pa., to the Atlantic.

In the Old World observations on earthquake vibrations have been reduced to a system, and instruments called Seismographs or Seismometers have been devised, which make an automatic record of the time, direction and force of the vibrations. Where such instruments are scattered over a country it is evident that the outline of the area affected by an earthquake shock, as well as the geographical position and depth of the centre of motion, may be accurately determined.

In Japan, where earthquake vibrations are almost incessant, an

* Since this paper was written I have received "Historical Notes on the Earthquakes of New England from 1638 to 1869," by Mr. William T. Brigham, published in the Memoirs of the Boston Society of Natural History, 1869. This contains notes upon two hundred and thirty-one earthquakes, with many interesting details.

extended system of observations has been instituted by Prof. Milne, which are likely to throw much light upon this subject.

In this country there are few Seismometers, and no carefully regulated system of observation has been yet adopted, but it is probable that the one good effect of the Charleston earthquake will be to excite an interest in such phenomena that shall result in the organization of a thorough system of observation. The officers of the Geological Survey and Signal Service Bureau are taking an active interest in the matter, and it is probable that observations on the movements of the earth will be added to those they are now making on the movements of the atmosphere.

When the data already collected in regard to the Charleston earthquake shall have been tabulated, it will doubtless be found that the displacements which occasioned the vibrations were located along a line parallel with the Alleghanies and at a depth of 10,000 to 20,000 feet, not under but westward of the city.

Inasmuch as no great change took place on the surface of the land in South Carolina, it has been suggested that the seat of the movement was under the ocean, and that important changes may have taken place in the topography of the sea bottom. It is quite certain, however, that such was not the case; for any considerable movement beneath the ocean in the vicinity would have resulted in a great wave upon the shore, such as have attended many other earthquakes, viz., that of Kingston, Jamaica, in 1692, of Lisbon in 1755, or that of Arica, Peru, in 1868. No wave at all is reported on the coast of South Carolina, though a distinct shock was felt on board a ship which had just left Charleston. This proves that the seat of the disturbance was not under the sea, but on the land, the vibrations passing from the land seaward. It is reported that a slight change in the depth of the water in Charleston Harbor has resulted from the earthquake, but no accurate observations have been made to test the truth of the report. In all probability the movement was in the old crystalline rocks beneath the comparatively modern deposits which underlie the surface, and consisted in a yielding to lateral thrust which ruptured and slipped some of the beds over others. Such fracture and movement would produce vibrations which would take the form of successive waves passing vertically, upward and outward in every direction from the focus of action. As the older rocks which underlie this region dip toward the east and have a strike north and south, an impulse

then, the earth's movements have been only the relatively gentle vibrations caused by the yielding of the flexed and fractured rocks of the upper portion of the crust to the ever acting and resistless thrust of the great unbroken tables of the Mississippi Valley and the Atlantic basin.

Earthquakes and Volcanoes as Measures of the Thickness of the Earth's Crust.

As is mentioned in the early part of this article, the first result of the discovery of the law of increase of temperature in going toward the centre of the earth, was the conclusion that the solid crust was not more than 50 miles in thickness, and below that was a sea of fluid or semifluid molten matter. Then mountain chains were supposed to be the result of the crushing together of solid sheets of rock as they followed the cooling and shrinking interior. The coat becoming too large, and adhering to the body, must wrinkle as the body shrank. Volcanic eruptions were supposed to be the oozing out of molten matter from the not distant zone of fused material, and all was harmonious in the geological world. Then came Professor Hopkins, Archdeacon Pratt and Sir William Thompson, in the character of disturbers of the public peace; they said that the crust would be broken up by tides if it was as thin as supposed; that the shell would be pulled about on the fluid nucleus by the attraction of the moon on the equatorial protuberance; and, finally, that the tenacity with which the figure of the earth was maintained under the varying pull of the sun and moon made it necessary to suppose that it was, as a whole, as rigid as a globe of glass, or even of steel. Sir William Thompson conceded, with some hesitation, that the crust of the earth might not be more than 2500 miles in thickness; further than that, he would not go. Since that time, awed by his great and well deserved fame, geologists have generally accepted the conditions he imposed upon them, and there has been a terrible struggle to reconcile volcanoes, earthquakes and the flexibility of the earth's crust with a solid interior. Some have gone back to Sir Humphry Davy's theory, that volcanoes were the product of intense chemical action in certain circumscribed portions of the earth's mass; and others have supposed that, between a thick external crust and a solid interior there was an intermediate zone of fused matter from which volcanic

ejections emanated. Mallet, who has displayed great learning and ability in his various papers on volcanoes and earthquakes, forbidden by Sir William Thompson's dictum from drawing molten matter from the interior of the earth to operate his volcanoes, contrived a method of manufacturing it on the spot. He proposed a theory that all the phenomena of vulcanism are due to the arching of the exterior strata composing the earth's crust, their final yielding to gravity and crushing down on to the contracting interior; the conversion of motion into heat producing all the thermal phenomena.

A fatal defect in this theory is that it gives no reason for the localization of the heat along the line of fissure from which the lava flows. All parts of the masses on either side must share in the motion and should also share in the heat, and we must look elsewhere for an explanation of the phenomena.*

There would have been no question of the truth of the old theory of vulcanism if it had not been raised by the physicists whose names have been mentioned, and it can now be seen that their objections have little force. Delaunay, of Paris, and Hennessy, of Dublin, have shown that the premises assumed by Thompson, Hopkins and Pratt in their attempted refutation of the old theory of a comparatively thin crust are not those of nature, and that their conclusions are, as a consequence, irrelevant and valueless. Their objections were aimed at an incompressible fluid interior and an elastic crust; conditions which do not and could not exist. Beside this there must be a viscous zone of considerable thickness in which the transition from the solid crust to the liquid interior is very gradual; and it is highly probable that the matter of this viscous zone is not only not itself affected by tidal movements, but that it acts as a buffer between the liquid interior and the solid crust. It should be remembered that the moon's attraction—the chief motor in oceanic

* In a review of Mr. Clarence King's report "On the Geology of the Country Bordering the Fortieth Parallel," the writer in 1879 suggested a simple explanation of the phenomena of vulcanism, viz., A slight arching of the crust of the earth along lines of fracture and elevation, in a measure relieves the pressure by which highly heated matter below is kept in coerced solidity. This relief of pressure causes the potential fluidity of this compressed matter to become actual, and thus reservoirs of lava are called into existence beneath the lines of fracture and arching. Finally the pressure from gravity being maximum under the tables of unbroken strata on either side, and minimum beneath the crown of the arches, this unequal pressure causes the lava to rise along the fissures and flow out in volcanic eruptions.

tides—is a force applied to a surface moving at the equator about a thousand miles an hour. Even a fluid as thin as water refuses to obey instantly an attracting body. The tidal wave of the ocean is always considerably behind the moon, and in some places where obstructed by topographical features it doesn't reach its destination until some time the next day. It is easy to see that in a tarry, pitchy mass the response to the moon's attraction would be far less prompt, and also that the tidal waves in zones of different depths and densities would not coincide, and might completely neutralize each other.

Every boy knows that if a flat rock is thrown from a cliff on to water some distance below, it is shattered almost as though it fell upon a solid; but the velocity of a falling body *in vacuo* is 16 feet the first second, 48 the second, etc., and with the resistance of the air, it is doubtful whether a stone thrown from a cliff 100 feet high reaches the water with a velocity greater than 50 feet a second, while the velocity of impact, if we may use the expression, of the moon's attraction is nearly 30 times greater than that, or 1466 feet per second. The resistance which the internal friction of a viscous body would offer to a force applied with such velocity would be enormously greater. Hence we must conclude that the tidal movement in such a mass even at the earth's surface must be very small, and if, as is the case in the interior of the earth, that mass were condensed and constrained by the weight of a crust even a hundred miles in thickness, it would be inappreciable. It should be remembered that the force of gravity acting upon a column of matter one foot square and having the density of the materials composing the earth at the surface, that is 2½ times that of water, is 5,280,000 lbs. for every mile, or 528,000,000 lbs. at the depth of 100 miles. Such a pressure must greatly increase the density of matter of any kind. The average density of the earth is 5½ times that of water, and it is plain that in matter of this density and so situated not only a tidal wave would be impossible, but any attraction which is constantly and rapidly changing its point of bearing must be practically powerless to distort the figure of the earth.

Flexibility of the Earth's Crust.

It is difficult to imagine how the advocates of the theory of a solid globe can account for the formation of mountain chains, the

loftiest and longest of which are quite modern, and it is not perhaps too much to say that these themselves are a refutation of their theory. It is evident that a heated solid globe, as it lost its heat, would either contract bodily as a red hot cannon ball does, or by the more rapid cooling of the outer surface, that would shrink faster than the interior, and crack in every direction; a process just the opposite from that which we find recorded in the earth's crust.

But there are other evidences of the flexibility of the earth's crust which are incompatible with the theory which ascribes to it great thickness. (1.) The lines of volcanoes which crown most great mountain chains are located along fissures which seem to be continuous for thousands of miles, and there is apparently good evidence that these fissures penetrate through the entire thickness of the solid crust. Sometimes the volcanoes are in simultaneous action for several hundreds of miles, and the materials ejected though showing much variety are often identical: facts incomprehensible on any other supposition than that they have been drawn from a common reservoir.*

(2.) Along all the coast lines the evidences of local changes of level now in progress, or included in the records of past time, are so numerous and striking, that the term *terra firma* seems singularly ill-chosen; for example, the shores of the Mediterranean abound in evidences of local depressions or elevation, or both, since it has been occupied by civilized man. Of these the temple of Jupiter Serapis at Baiæ, is one of the most famous, but by no means the only example.

On our own continent the southern portion of Greenland has been gradually sinking for several hundred years; Labrador and New Foundland are rising; Prince Edward's Island and Cape Breton, according to Gesner, have sunk many feet since they were first occupied by the whites. In Nova Scotia the land is rising; in Northern Maine it is sinking, as, also, at Cape Cod and Martha's Vineyard and on the shore of Long Island and New Jersey. Here the subsidence has locally varied from two to twelve feet during the last century. In the West Indies, there are many evi-

* Darwin mentions (Trans. Geol. Soc., March, 1838), that in the Andes the volcanoes Osorno, in lat. 40° S., Concagua, in 32° S., and Coseguina, in lat. 13° N., burst into eruption simultaneously on the 20th January, 1835. The more remote of the three are 3700 miles apart.

dences of local change of level; in some cases, of elevation, others, of subsidence. In California, we find traces of recent and local flexures of the coast which are very striking; at San Diego is an old beach strewed with shells which have not yet lost their colors, twenty feet above the present sea-level. At San Pedro, the port of Los Angeles, the limestone rocks which form the sea cliffs are bored by *Pholas* eighty feet above the water; on the south shore of San Pablo Bay, at a height of twenty feet above the water, is a bank of oyster-shells, four feet in thickness; this descends toward the south, and disappears beneath the surface of San Francisco Bay. Puget Sound, with its many branches, is only the submerged valley of a great river which ran out to sea through the Straits of Fuca when the coast was much higher than now; but the shores are terraced to the height of 1600 feet above the present water-level; showing that, in recent times, they have been much lower than now. Similar facts with these have been reported from the shores of all the continents, and the islands afford more striking examples of the changes of level; the Windward Islands are only the summits of a lofty mountain chain which was once all above the sea-level, as is shown by the community of species in animals and plants. The Islands of the South Pacific are, also, the summits of mountains which have been gradually submerged as has been shown by Dana and Darwin. Coral reefs which are formed only within 150 feet of the surface, now extend down in continuous walls, 2000 feet below the water; the growth of the coral having kept pace with the gradual subsidence. Elisé Reclus, in *La Terre*, and Professor Prestwich, in his *Geology*, give maps, showing the fluctuations of level now in progress along coast lines, and whoever will examine these maps, will find it difficult to reconcile these oscillations of the land with a globe solid to its centre, or even with a thick crust. But the changes of level now taking place, proceed so slowly, that the record of 150 years, during which geological observations have been made, or even that of the long period covered by human history, is insignificant, compared with that of the geological ages. Indeed, historical geology is, for the most part, but a transcript from the monuments left by successive and local subsidences of the land, influxes of the sea, and the deposition of strata containing relics of the marine and terrestrial life of the epochs in which these inundations occurred. Scarce any portion of any continent is without traces of

the presence of the sea, and, while some of these submergences were, doubtless, caused by great tides which ebbed and flowed from one hemisphere into the other, in the manner suggested by Adhemar, it can be easily shown that most of them were occasioned by local subsidences of the land.

All these lines of evidences, furnished by earthquakes, mountain chains, volcanoes and terrestrial oscillations, converge to one point, and, in combination, go far to prove that the earth's crust is relatively thin, and that its interior is fluid or viscous.

A priori considerations confirm this conclusion. If, as all believe, the earth was once a globe of molten matter which has cooled by radiation from the exterior, it seems impossible that the first formed crust could have sunk to the centre, and there laid the foundation of a solid structure, subsequently built up to the surface. Because, first, there is no probability that the superficial crust had a higher specific gravity than the underlying fluid; and, second, if its gravity were greater, and when broken up its fragments sank, they must soon have been melted by the greater heat below; and when, by this process, the outer zone of the earth had acquired a pasty consistence, its cohesion could not have been overcome by sheets of crust, even if a little denser. Hence, a cool, external crust, a hot, viscous zone and a hotter fluid nucleus seem logical necessities.

Proximate Causes of Earthquakes.

Atmospheric Conditions.—If it is true, as claimed on the preceding pages, that earthquakes are the vibrations attending the folding and breaking of rocks which have been in a state of strain, it is evident that the provoking cause of any special paroxysm might be a comparatively trifling affair,—some feather that should break the camel's back. Thus, we have reason to believe that atmospheric conditions may precipitate these catastrophes. The pressure of the atmosphere on the earth's surface is 14.7 pounds to the square inch,—that is, a little over 2000 pounds to the square foot, or about 30,000,000 tons to the square mile. Now, it sometimes happens that the mercury oscillates two inches in the tube of a barometer in connection with some violent storm; and it is true that the areas of low and high pressure change position quite rapidly. Hence, if it should happen that the underlying rocks

were from lateral pressure in a state of strain that had nearly reached the limit of resistance, a change of atmospheric pressure equivalent to two, or even one inch of mercury (equal to 1,000,000 or 2,000,000 tons per mile), might be the cause of a rupture. So, the popular belief, that peculiar atmospheric conditions have had an influence in causing earthquakes, is not so absurd as it might seem.

Accumulation of Sediments.—Another cause which has certainly operated to disturb the static equilibrium of the earth's crust, is the transfer of the products of erosion from the land to the bottom of an adjacent sea basin. Over all land areas where the rainfall is considerable, there is a constant wearing away of the surface by chemical and mechanical agents. About one-fourth of the material removed is dissolved and may be carried to the opposite side of the earth before it is precipitated; but the other three-fourths, in the form of gravel, sand and clay are simply held in suspension by running waters and are deposited as soon as their motion is arrested. Rivers, rivulets and shore waves are constantly engaged in transporting material from the land to the deeper water bordering the coasts; there spreading it to make new series of sedimentary deposits. As these accumulate they not only impose new burdens on the underlying rocks, but by acting as a blanket and preventing the escape of heat, they promote the softening and weakening of a belt of sea bottom. This process has produced great changes in the surface topography of many continents, and it is credited with the formation of a number of littoral mountain chains. The blanketed belt of off-shore sea bottom softened by heat, yields to lateral pressure, and is forced up in a series of faults and folds. There is little doubt that the loading of the sea bottom with the products of erosion has been one cause of the earthquake vibrations which have been so frequent along our Atlantic coast.

Periodicity of Earthquakes.—Very naturally an effort has been made to connect earthquakes with the changing relations of the sun and moon. M. Perry, of Dijon, France, has tabulated the records of 2225 earthquakes which occurred between the years 306 and 1845. Of these he found that 1712 took place in winter and spring, and 1335 in summer and autumn. By Mr. Robert Mallet between 6000 and 7000 earthquake shocks are enumerated as having taken place in Europe only. Judging from all these it seems that earthquakes are a little more frequent when the attractions of

the sun and moon are combined or opposed—that is at new and full moon—and when the earth is nearest the sun.

These data, although still defective, tend to support the theory of the fluidity of the interior of the earth, and confirm the testimony of volcanoes and the secular oscillations of the earth's crust.

Areas of Exemption.—Probably no part of the earth's surface has been always free from earthquakes. Nevada, Utah, New Mexico and Arizona were in Tertiary times more completely broken up and devastated by earthquakes and volcanoes than any other country known to us, but in that same region profound peace prevailed from the Cambrian to the Cretaceous age, many millions of years. Since the Tertiary the Colorado plateau has been remarkable for its stability. This is shown by the sandstone pillars several hundred feet high standing at the mouth of the Cañon of Chelly, and in the Colorado valley near the junction of Grand and Green Rivers. These columns have been formed by the slow removal of the material around them, a work of ages; and earthquakes would have brought them down in ruins, as they have shattered the monuments of Baalbeck, Tanis and Karnak.

Bibliography.—"First Principles of Observational Seismology," Robert Mallett; "The Facts and Theory of Earthquake Phenomena," R. Mallett, Reports of British Association, 1850–58; Various papers on earthquakes, by R. Mallett, in the Philosophical Transactions and Transactions of the Royal Irish Academy; "Geological Theories of Elevation and Earthquakes," W. Hopkins; "Report Brit. Assoc." for 1847; Oldham and Mallett on "The Cachar Earthquake," Quarterly Jour. Geo. Soc., 1872, p. 255; Scrope's "Volcanoes"; Lyell's "Principles of Geology," vol. ii.; Prestwich, "Geology," vol. i.; Milne, "Earthquakes of Japan"; "Catalogue of Earthquakes of Europe and Adjacent Countries," J. P. O'Reilly, Dublin, 1886; "Underground Temperatures," J. Prestwich, Proc. Roy. Soc., 1886; "Water in Volcanic Eruptions," Prof. J. Prestwich, Proc. Roy. Soc., 1886; "Internal Fluidity of the Globe," M. Delaunay, Geol. Mag., vol. v., p. 507; "Figure of the Earth," Archdeacon Pratt, 1860; "Rigidity of the Earth," Sir Wm. Thompson, Phil. Trans., 1863; "Inequalities of the Earth's Surface," Rev. O. Fisher, Phil. Trans., vol. xii.; Dana, "Geology"; LeConte, "Geology"; L'Apparent, "Geologie"; Hartwig, "Subt. World."

ELECTIVE STUDIES.*

BY F. A. P. BARNARD.

OPINIONS of educationists have long been divided on the question whether or to what extent it may be proper to allow to undergraduate students in college freedom of choice in the selection of their studies. The discussion, after having apparently begun to flag, has been recently resumed with more activity than ever. Until some time later than the beginning of the present century, it is believed that in every college in our country an invariable curriculum of instruction was rigorously enforced. When at length there began to be admitted some slight relaxation of the severity of this rule, the earliest steps taken were cautious in the extreme, and so slight as to be almost insignificant. At Yale College, up to a quite recent date, the liberty of choice was allowed to the student only during three months of the junior year, and embraced no studies except Fluxions (the Calculus), Hebrew, Greek, French, and Spanish. An interruption of so brief duration could scarcely affect sensibly the general character of the course. In our own College no option in the selection of studies was allowed until 1864, when the Calculus was placed on the optional list; but as this subject had not for some time previous been taught at all, the innovation hardly produced a sensible change. To those who selected the subject one hour was allowed weekly during the senior year in place of Greek. It was not until 1872 that the elective system was avowedly admitted into the College, and then only for the senior year and partially. Of the fifteen hours of instruction in class weekly, eight continued to be occupied with obligatory studies, while for the remaining seven a choice was allowed among a considerable range of subjects, including Greek, Latin, the Calculus, mathematical physics and philosophy. Eight years later this liberty of choice was materially enlarged and extended to the junior year also. With the junior class obligatory studies were limited to four hours per week, and with the senior to two hours only. The French, German, Italian, and Spanish languages, more-

* From Annual Report of the President of Columbia College for the year 1885–86.

over, having been in this year made a part of the regular curriculum of study in every one of the four years of the college course, an option between these languages was given to the sophomores and freshmen for two hours per week; each individual to be confined to a single language. In 1884 this system received a new modification, with the senior class in the way of extension, and with the juniors in that of restriction; all the senior hours being devoted to elective studies, while with the juniors the free hours were reduced from eleven to five. This last change as to the junior class was made by the trustees on recommendation of a majority of the Faculty—a majority in which the undersigned was not one and concurring, having opposed the adoption of the recommendation by his vote, though unwilling in a matter of so great educational interest to interpose a veto. This explanation is made that his position upon this question may not be misunderstood. It is probably too early as yet to appeal to results as a test of the wisdom of the change; but there is already reason to believe that they have not been in all respects advantageous. It is known, for example, that in a number of instances parents in New York who had designed to enter their sons in this College have sent them elsewhere, in consequence of the limitation put by this recent action upon the freedom previously allowed in the selection of studies during the junior year.

Most of the leading colleges of the country are admitting the elective principle more or less freely. In 1876 Yale College extended her very limited optional list above-mentioned from a minute fraction of the studies of the junior year to about one-fourth of those of both junior and senior years. Only last year she has once more enlarged it, so that now, out of sixteen hours weekly, seven only are given to prescribed studies in the junior year, and three hours only in the senior. At Princeton one-third of the time is given to elective studies weekly during the junior year, and more than one-third during the senior. At Bowdoin about four-fifths of the studies are prescribed during both junior and senior years. At the University of Pennsylvania and at Williams College the published announcements indicate that the time of the two later years of the course is about equally divided between prescribed and optional studies. At Rutgers it is allowed to elect one study during the junior and senior years. At Union one-third of the time is given to elective studies

during the senior year only; but this institution offers also elective courses, a classical and scientific course running through the entire four years. At Brown electives are offered as early as the sophomore year, when they occupy about one-fifth of the time. In the same institution, in the junior year, they extend to one-third, in the senior to about one-half. At Amherst electives cover about one-half the time during the second and third of the three terms of the sophomore year, and during the whole of the two later years. In the University of Michigan all the studies are elective after the close of the freshman year; and at Harvard University it is a matter of notoriety that there are no prescribed studies at all.

In this variety of practice, while it is obvious enough that the colleges of the country are steadily drifting away from their policy, so long stoutly adhered to, of maintaining a severely prescribed curriculum of study, we look nevertheless in vain for any distinctly apparent principle guiding and determining their action. This new departure would in fact seem in many instances to have been entered upon rather in deference to a presumed popular demand, than as a consequence of any very profound study of the principles of educational philosophy. To a certain extent, however, it has been forced upon college authorities as a necessity resulting from the multiplications of the subjects with which they have overstocked their scheme of operations. This enlargement of the amount of matter professedly taught has carried with it the inevitable alternative of superficial teaching on the one hand, or the restriction of each student, on the other, to a portion only of the entire programme offered. Many of the subjects introduced, since this century began, into the scheme of collegiate instruction have been admitted on the ground of their usefulness, the assumption being tacitly made that the most important business of the college is to instruct rather than to educate. And when it has been objected that the effect of these additions was to crowd out the studies heretofore regarded as essential to thorough mental discipline, the reply has been ready that the new studies are just as efficacious to this end as those which they displaced. On this point there has arisen an active controversy, the parties to which are not likely to be reconciled. Whatever on that point may be the decision, it is an unfortunate consequence of the adoption on a large scale of the elective principle, that the significancy of college degrees is likely in future to be sensibly neutralized and their value depreciated. This evil

might be obviated if colleges everywhere were to adopt the rule of the University of Virginia, to confer a degree in arts only on such as use their freedom of option in the choice of studies in such a way as to bring their course into practical conformity with the curriculum for which such degrees were first granted; all others to receive degrees of different names, or certificates of proficiency without titular degrees.

But though the principle of election in study has been in many institutions adopted as to some extent an unavoidable necessity, it has been generally felt that to allow it to cover the whole undergraduate course would be a serious error. In the opinion of educators generally such an extension would be to defeat the main object for which colleges exist, which is to develop, by judiciously directed exercise, the intellectual faculties of men, and to train them to habits of systematic and sustained activity, such as may fit them to engage with effect in any species of effort which may lie before them in life. And whatever may be the views of some new lights in educational philosophy, it is not the general belief that this object can be effected by substituting any miscellaneous group of subjects of study chosen at random, in place of that body of judiciously chosen and felicitously associated subjects which have, down to a recent date, constituted the close curriculum under which our fathers qualified themselves for degrees in arts. The majority of colleges, therefore, while admitting the principle of election, have restricted it to the later period of the undergraduate course, some confining it to the senior and even to a portion of that year, others extending it wholly or partially into the junior year, and a few carrying it back into the sophomore. In one noted instance above referred to, all the studies of the college course, from the beginning of the freshman year onward, have been made elective.

As in comparing the varieties of practice of the colleges in this matter we discover no general principle determining their action, so neither in their publications do we find any explanation of these diversities. The general preservation of the close curriculum during the earlier years would seem to be a consequence of an abiding conviction that the essential end of a liberal education, viz., the systematic training of the mental faculties, cannot be secured without it. The abandonment of the same in the later years is evidently an expedient rendered necessary by

the fact that the number of subjects which the institution has undertaken to teach is too great to be crowded into a course of study imposed upon all. It is the latter condition principally which seems to have determined the point at which the line has been drawn in different colleges, between the obligatory and the elective studies, and which has fixed it earlier or later according as the pressure has been greater or less. Every college naturally desires to make its scheme of instruction as comprehensive as its resources will allow; and every enlargement of this scheme seems an additional step toward the attainment of that character which all are ambitious to acquire—that of a school of universal knowledge. But as the resources of different institutions are unequal, it will always happen that some are materially in advance of the rest.

Considerations of this character, however, were not those which fifteen years ago determined the introduction of the elective system into Columbia College. This step was taken in consequence of the observed fact that our students at the close of their third year in college have in general reached an age to which educational theories of study as a mental discipline are inapplicable, and at and after which the more legitimate end of study is the increase of knowledge. During the period of childhood and early youth the power of educational influences is very great, and they may accomplish much in giving tone to the intellectual character; but they are impotent to determine its distinctive quality or to obliterate or transform the stamp which has been impressed upon it by the hand of nature. Education is not a necessity to the growth of the mind any more than to that of the body. The minds of savages grow, and those of the little street Arabs for whom nobody cares, who attain often, nevertheless, in the rough schooling of the world, a sharpness of cunning which enables them often easily to outwit the most highly cultured intellects among the more favored classes socially superior. It is during this period of growth that the mind like the body is amenable to educational influences. There are handicrafts which can never be perfectly acquired unless commenced in childhood. An adult may learn to speak a foreign tongue sufficiently well to be understood, but never so well as to make it pass as his vernacular. So if a limb be kept during the growing period in a state of enforced rest, it will shrivel and become atrophied, while if it be kept constantly and energetically in action, it will attain abnormal proportions. In like manner the

mental faculties if, by a judiciously selected course of study, they be maintained during the same growing period in a state of healthful activity, they will attain a vigor which they could not have spontaneously acquired. But experience has shown that in a given individual mind all the faculties are not equally responsive to the influences employed to excite them; and that of many minds subjected to the same disciplinary regimen, no two will strikingly resemble each other in the results of their development. In one the imagination will be the prominent faculty, in another the understanding. One will find the highest satisfaction in the study of natural forms, another in the investigation of natural forces. To one the structure of language will afford a favorite field of inquiry; to another the creations that are built up out of it, poetry, oratory, history, fiction. One will revel in exact science, another in abstraction and speculative philosophy. The effect, therefore, of disciplinary training during the period of mental growth is to develop and bring into activity the distinctive characteristics of each mind, and to discover the field in which each is most capable of putting forth effort successfully. When this point is reached, to compel an individual to occupy himself with efforts for which he is constitutionally unfit, is a serious educational error. We are justified in saying, therefore, that the work of education, during the period of mental growth is in great measure, whether consciously to the teacher or not, a tentative work, of which the result is to ascertain in each particular case what the individual is fit for. After that the course logically indicated is to occupy him with that for which he is fit.

During the growing period the studies should be so varied as to offer every faculty of the mind an equal inducement to exert itself—to provoke it, so to say, to activity. If, in any case, there should happen to be no predominating characteristic, all the powers will yield equally to the solicitation, and there will be produced—what is so often spoken of as desirable, and so generally assumed to be universally attainable, but which is so rarely seen—a truly rounded culture. The more usual result, however, is that the tentative process brings strongly out some peculiarity, some idiosyncrasy, which makes a man more or less one-sided in his mental character, and incapacitates him for prosecuting effort with equal success indiscriminately in all directions. This point can hardly be said to have been conclusively reached until the mind has attained the

period of natural maturity; the period, that is to say, at which it would mature if left to develop itself unaffected by any constraining scholastic influences. Previously to this it retains more or less the plasticity which distinguishes the period of childhood, and is capable to some extent of modification of character. At maturity it takes its final shape, and although by exercise it may gain in strength, it undergoes no further change in respect to the balance of its faculties.

The point, therefore, at which, in a continuous educational course, an obligatory curriculum of study should give place to unlimited freedom of choice on the part of the student, should be fixed rather with reference to maturity in years than to the degree of advancement in the four years' round of college study —a round substantially invariable for all colleges, however they may differ with each other in the average ages of their students. If this principle is admitted, the important inquiry will be, what is that degree of advancement in age, at which a human being may be supposed to have become so far intellectually developed as to have made his natural and unalterable mental constitution distinctly apparent?

The answer to this question may be derived from psycho-physiological considerations, or from the general judgment of past generations as inferred from the age at which, during the seventeenth, eighteenth, and the earlier part of the nineteenth century, a period during which an invariable curriculum of study was enforced in all our colleges, it has been usual for young men to complete their undergraduate studies. Looking at this question from the first point of view, it is matter of common observation that the human form, in its normal growth, attains its full dimensions at or about the end of the nineteenth year, or if there is any further growth after this period it is insignificant. What is true of the osseous and muscular tissues, it is reasonable to suppose must be equally so of the brain; and in point of fact it is found that the understanding is fully developed in young men and young women at an age not over nineteen. After this age, therefore, all educational discipline persisted in, in the hope of stimulating into vigor and activity faculties which have refused to respond to the solicitations of previous years, is for the most part thrown away. And from this time forward there can be no doubt that the most advantageous results will be obtained by presenting to the mind only those

subjects which are most in harmony with its own constitution, and with which it is most fitted to deal.

If again we look for evidence of the views of past generations on this subject, we shall arrive at a conclusion entirely identical with the foregoing. They will be found if we can ascertain the average age at which young men graduated from college a century ago. Unfortunately, no one has hitherto endeavored to collect the statistics of this question, and the data are scattered. They can be obtained at all only for persons conspicuous enough to have had the particulars of their lives recorded in cyclopædias or biographical dictionaries. As the result of a hasty and extremely cursory inquiry, the undersigned, in his annual report for 1880, presented a list of eighty-one eminent men, all of them graduates of the early years of this century or earlier, and none of whom graduated at a more advanced age than eighteen. In a recent inquiry of the same kind, six hundred consecutive pages of a cyclopædia have been examined, and in these have been found notices of two hundred and thirty persons, whose ages at graduation were given, of whom none graduated later than the middle of this century, and most of whom belonged to the two centuries preceding. As to graduating ages, these two hundred and thirty are distributed as follows:

Age.	Number.	Age.	Number.
9	1	20	24
13	3	21	22
14	3	22	23
15	7	23	18
16	6	24	10
17	19	25	6
18	36	26	8
19	43	31	1
Total to 19	118	Total 20 to 31	112

It appears from this exhibit, that the age at which the largest number graduated was nineteen, and the age at which, next in order, graduations were most numerous, was eighteen. The average age, of all up to nineteen inclusive, was seventeen and a half. The average of the entire number was 19.87, which, as will be seen from the statement given earlier in this report, corresponds very nearly to the average age of our students at present at the end of the Sophomore year. In an inquiry like the present, however,

graduation at advanced ages (above twenty-three, for example) should be allowed little weight; for there are many young men, those of limited means especially, whose entrance into college is, by force of circumstances, delayed much beyond the time when they would have willingly entered, had it been possible. In the college class of the undersigned, for instance, in which the average age at entrance was about fifteen, there were three or four over twenty-five, and one over thirty-two. It is, furthermore, to be observed that, in the above enumeration, numerous graduates of the United States Military Academy are included; and that, for some reason not apparent, but possibly political, the average age of graduation is considerably more advanced in the Academy than in civilian colleges.

The conclusion is, therefore, justified, on all grounds on which the question can be placed, that, after the age of about nineteen years, it is the most judicious educational policy to adapt the studies of the individual to his clearly ascertained mental characteristics. This may be done, either by prescribing to him such a course of study as his instructors may judge, as the result of observation, to be best adapted to his capacities, and, therefore, most likely to be profitable to him, and requiring him to pursue it; or, by giving to himself the liberty to choose such as are most in harmony with his tastes. Either course will naturally lead to results substantially similar; but better than either would be a combination of the two—that is to say, to permit the student to choose: but to require him to submit his choice to his instructors for ratification.

The plan of elective study adopted in this College in 1880 was in accordance, in the main, with this theory. An almost unlimited freedom in the choice of studies was permitted to the Junior and the Senior classes, history, political economy, and the English language and literature only being obligatory, these being regarded not as disciplinary studies, but as being a part of that knowledge which should be possessed by every well-educated man. From the reports of the undersigned for the years 1882 to 1885, inclusive, it appears that the consequences following the introduction of this system, in the improvement of the scholarship of the Junior and Senior classes, were striking and palpable. In November, 1884, however, the freedom of election in the Junior class was largely restricted, being reduced from eleven hours per week to five. As this change was directed after the academic year 1884–5 was con-

siderably advanced, and, therefore, after the elections for the year had already been made, it could not be carried into effect until October, 1885, and it is as yet too early to draw any inferences as to the consequences of the change as regards scholarship; the records which have been gathered under the new system covering a period of only four months. One result, however, which was not anticipated and was certainly not intended, has been to reduce considerably the number of persons electing the modern languages, especially the German, after the Sophomore year. The new rules prohibit to the two lower classes the choice of any foreign language but the French or German, unless for very special reasons approved by the head of the department; and they, moreover, require that the language, originally elected in the Freshman year, shall be persisted in to the end of the Junior year, if any modern language is chosen in that year at all. But, inasmuch as no modern language is among the compulsory studies of the Junior year, it happens that the privilege allowed to the Juniors in this matter is negative rather than positive—that is, not a privilege to elect a modern language, but a privilege not to elect any at all. Thus, it happens that the operation of the rule is prejudicial to the department, and reduces rather than increases the attention paid to the modern languages in College. It is worth consideration, whether the system, as it existed previously to November, 1884, might not, with propriety, be restored.

The following statements will show the relative numbers of individuals who have, this year, elected each of the several studies offered to their choice:

Studies Elective by both Juniors and Seniors.

	Seniors.	Juniors.	Total.
Number in class,	60	57	117
Greek,	38	18*	56
Latin,	31	17*	48
Mathematics,	8	27	35
Physics,	20	35	65
Botany,	9	23	32
French,	27	22	49
German,	16	13	29
Spanish,	20	1	21
Italian,	4	2	6

* Besides this elective Greek and Latin, the same languages are compulsory for the Junior class, two hours per week throughout the year.

Studies Elective by Seniors only.

	Number Electing.
Number in class,	60
English,	24
Astronomy,	40
Philosophy,	21
Chemistry,	11
Political economy,	15
Constitutional History of Europe,	16
Constitutional History of England,	8
Geology,	17
Anglo-Saxon,	24
Hebrew,	3

Modern Languages Elective by Sophomores and Freshmen.

	Sophomores.	Freshmen.	Total.
Number in class,	59	68	127
French,	33	37	70
German,	23	31	54
Italian,	2		2
Spanish,	1		1

The relative numbers in the entire College electing modern languages are:

	Numbers Electing.
Total number of students,	247
Number electing French,	119
" " German,	83
" " Spanish,	22
" " Italian,	8

Attention was called in the last annual report of the undersigned to the fact that the study which had been elected by the largest number free to choose, was the Greek. For every previous year, since the system was established, both Latin and physics had stood above this language in the order of apparent acceptability. In the present year, physics has resumed its advantage, but Greek continues to lead all the rest. What makes this the more remarkable is, that Greek is compulsory during three years of the course, and yet is a favorite elective besides. It is gratifying, also, to note that so severe a study as the mathematics is sensibly gaining in favor, and commands the choice of a third part of the number to whom it is offered. Among Senior electives, astronomy, as usual, easily leads, and Anglo-Saxon has made an extraordinary advance, having, the preceding year, been elected by only a single individual.

ON A METEORIC IRON FROM SOUTH CAROLINA.

BY WILLIAM EARL HIDDEN.

THE meteorite, here described and illustrated, " was found, in the year 1857, in the northwest corner of Laurens County, South Carolina, and was deposited in the cabinet of the Laurensville Female College at Laurens C. H. very soon after its discovery. It was sent to the New Orleans Exposition of 1884–85, where it formed

FIG. 1.

Meteoric Iron (Cuboidal), from Laurens County, S. C. (natural size).

a part of the State Exhibit of South Carolina." The writer first saw it there, and was, enabled, through the kindness of the State Commissioner, to gain possession of it.

An analysis of a small piece, cut from the mass with some difficulty, yielded Mr. J. B. Mackintosh the following results:* Iron, 85.33; Nickel, 13.34; Cobalt, 0 87; Phosphorus, 0.16 = 99.70; Sulphur and Carbon in traces. Thus, it is seen, that in composition this mass of meteoric iron is of unusual interest, the percentages of Nickel and Cobalt being uncommonly high.

* Analysis completed June 24th, 1885.

Fig. 1 shows the mass in its exact natural size, and exhibits well the natural appearance of the Widmannstätten figures brought out on this surface by etching with dilute nitric acid. The rough surface, surrounding the smooth, countersunk, etched panel, was purposely left in its original condition, so that the homogeneity of the mass could be readily seen. The extension of a few lines of the panel surface can be traced running over the rough exterior, and other lines are seen to be parallel when not continuous. The very apparent tendency of the perpendicular lines of this figure to form a right angle with the upper and lower sides, and a parallelism to the left and right-hand edges, confirms the belief that we have, in this mass of meteoric iron, a well-marked relation to a cuboidal form: a shape very rarely, if ever before, observed in masses of this nature.

FIG. 2.

Widmannstätten Lines on the Laurens County, S. C., Meteoric Iron (natural size).

Since the illustrations are made by a photo-engraving process (Ives's), we can look at them minutely and with satisfaction, knowing that nothing is misrepresented, or incorrectly drawn.

On five sides of this mass, an angle of 90° seemed to be very closely approximated, which tends to prove the form to be cuboidal by design rather than by accident. The other surfaces were either rounded, deeply pitted, or they presented the appearance of having been broken apart, by occult causes, from parts of the mass which

are now lacking, these missing parts, possibly, completing the cuboidal form on all sides.

Fig. 2 represents part of a surface parallel to Fig. 1, but distant more than an inch from it, at the back of the mass. It is placed on the page in its natural relative position to Fig. 1, the lines in both figures being parallel.

Of special interest is the broad, double line on the right-hand side of Fig. 2. From it, pointing upwards at an angle of about 70° from the perpendicular, are seen lines, diverging right and left, at the same inclination, thus showing that twinning has occurred in this iron, parallel to an octohedral face. This broad line the writer has traced over the entire exterior of the mass, and

FIG. 3.

Laurens County, S. C., Meteoric Iron (transverse section).

identified it with the line in Fig. 1, situated 2 centimeters from the right-hand edge of the panel. The homogeneity is thereby clearly proven.

The sharpness and general perfection of the Widmannstätten figures in this iron has seldom been equalled.

Fig. 3 represents a small surface situated at right angles to the lower right-hand edge of Fig. 1, and is, in the writer's opinion, the place of impact where this mass struck the earth. It is of interest to compare the fineness of these lines with those of the other figures; the parallelism of the lines to the longer straight edge—the cuboidal face—is also noteworthy.

The presence of hydrogen was proven by simply rubbing powdered sulphur over the smoothed surfaces, when, instantly, the disagreeable odor of hydrogen-sulphide was made noticeable. In the action of nitric acid, carbon was also proven to be present, probably as graphite.

Lawrencite (ferrous-chloride) was noticed in the solid state, and

in Fig. 2 the dark, rhomboidal spots represent the situation of this rare mineral in the mass.

This meteorite approaches that of Babb's Mill (Tennessee), and of Kokomo (Indiana), in its high nickel percentages, and in the fine development of the Widmannstätten figures, to that of Smith Mountain (North Carolina), described by Smith and Kerr. It is the fourth meteorite found in South Carolina thus far, the others being known as the Bishopville (stone), Chesterville, and Ruff's Mountain (Lexington County) meteorites.

I here extend to Mr. Mackintosh my thanks for his kindness in making the analysis here given, and to Mr. R. W. Milner, of Laurens C.H., South Carolina, for his information as to the history of this very interesting mass of meteoric iron.

THE MENDHEIM CONTINUOUS GAS-FURNACE FOR BURNING FIRE-BRICK AND PORCELAIN.

BY THOMAS EGLESTON, PH.D.

In a recent publication,* I had occasion to call attention to the Mendheim gas-furnace for burning dolomite, which has, for some years, been used at Hörde in Germany, and has given the greatest satisfaction there. This furnace is not only applicable to this special purpose, but also to the manufacture of any articles which require to be burned at a high temperature and then more or less slowly cooled, such as fire-bricks, refractory wares, porcelain and pottery. The principle, on which it is constructed, is that of regeneration, by means of the heat contained in the articles manufactured, which are, themselves, cooled down by the current of air, which passes through them, abstracting their heat, and then using the air so heated to render the combustion of the gases, when high temperatures are required, more active. A double effect is gained in this way. The articles, which are already finished in the furnace, have the heat they contain slowly absorbed, and transferred where it can be utilized, thus avoiding its loss, and they do away with the expensive checker work, constructed gen-

* "Transactions, American Institute of Mining Engineers," vol. xiv., p. 465.

erally underneath the furnace, which needs constant attention and repair, and substitute for it the articles which are being manufactured, so that this part of the furnace becomes a source of profit rather than of outlay. This is not, however, the only economy of which this furnace is capable. There is always in every furnace a certain amount of heat which is absorbed by the masonry of the furnace itself, more or less of which is radiated from its walls, and is thus lost. This heat is, for the most part, regained by using the top of the furnace for drying and tempering floors. While these floors are generally not sufficient for the entire output of the furnace, and cannot, therefore, do away altogether with the fires for drying-kilns, it can do a certain part of it, and thus reduce materially the amount of fuel which is directly used. The principle of the kiln, therefore, involves the saving of fuel, by first transforming it into gas, then utilizing the wares burned in the furnace as regenerators, and further using the heat, that would otherwise be lost by radiation, as a means of preparing the material to be manufactured, to fit it to enter the furnace, without deteriorating too much the calorific power of the fuel, by the introduction of moisture, which would cause an absorption of heat. By such a system as this, smoke is entirely avoided, as well as the danger of fouling delicate wares with ashes, which are always carried over with the flame in direct firing.

The gas for heating the furnace is made in two producers, a, a^1, Fig. 3, placed at one end of the series of single chambers, which constitute the kiln. They may be of any construction which may be in use, or which may be suited to the particular kind of fuel which can be had in the district, and which is to be used in the producers. The gas from the producers comes off from the short flues attached to each one of them, and enters the flue, b, which runs parallel to the end of the kiln, and at each end of which there are valves, c^1, c^2, which allow of its passing into the conduits, d^1 or d^2. The chambers of the kiln, Figs. 1 to 3, are numbered consecutively from 1 to 18. The flue, d^1, d^2, runs in front of all of these chambers, below the level of the ground. A flue, b^1, passes underneath each chamber and ends at the back of it, as shown in the cross section, Fig. 1. At the point where each one of these flues, b^1, enters the flue, d^1 and d^2, is a valve which is controlled from the floor of the works, and which allows of either regulating or of cutting off the supply of gas altogether from any one of the

chambers of the kiln. The gas, and the air in its combustion, passes through a series of flues, which run backwards and forwards under the bottom of each chamber, as shown in the cross-section Fig. 1, and in the longitudinal, Fig. 2, and enters the chambers through a series of openings made in the floor, and shown in chamber No. I, Fig. 3. It then passes down through the flues, *f*, into the next chamber, the two end chambers, I and XVIII, IX and X being connected by the flues, g^1 and g^2 When it has passed a sufficient number of chambers, to abstract the excess of heat which it contains, it is passed into the flue, *h*, in the dividing wall, and goes from there into the underground flue, *i*, which connects with the chimney, *k*. The connection between *h* and *k* is made by means of an iron valve, which is always under control, so that as many chambers as it is desirable may be connected with, or cut off from, the canal, *i*, so that the gas can be made to enter the chimney at any required temperature. By this arrangement, also, any one or more of the chambers may be left out of the series when desirable. We will suppose that kiln No. I is to be fired. Behind it, there will be chambers XVIII, XVII, XVI and XV, which have been fired and are cooling down. The hot air from them, passing successively through the openings, *f*, in the side walls, enters the flue in the end wall, passes down and outside of the chamber, XVIII, into the flue, g^1, passes up the inclined flue and mixes with the gas which passes from the flue, d^1, by means of the valve, *e*, into the flue, b^1, which runs under the centre of the floor of each chamber, where, combustion taking place, the products of combustion pass through the holes in the floor up into the articles to be burned, and, having traversed them, pass through the side openings into the chamber II, from there into chamber III, and, being cut off from chamber IV by the valve, they pass through *h* into *i*, and so to the chimney. The chamber No. I thus receives the heated air from four chambers behind, which have been burned off and are cooling down, and gives up its surplus heat to two others, which have been freshly filled and are being dried previous to being fired. Chambers IV and V, having been emptied, are, during this operation, being filled so that when chamber No. I is burned, and chamber No. XV is cool enough to be emptied, and is cut off from the series to be opened, chamber No. II is fired, and chamber No. I becomes one of the series to progressively heat up the air to the high temperature required for combustion. Thus, to burn a single chamber, at least seven others

are required, and the heat is so entirely absorbed that not only is the combustion most perfect, but the cooling down by the cold air, which is introduced into the first cooling-off chamber, is so progressive and so very gradual that there is not the least danger to the wares being damaged by the abstraction of their heat.

When the material being fired contains so much moisture or the fuel used is so damp that it would not be profitable to use the gas, the moisture, given off during the first part of the operation, is conducted to the flue, *l*, Figs. 1 and 2, which is placed in the upper part of each chamber. This flue is opened and closed with a fire-brick damper. When it is necessary to use it, the air from one of the chambers which is cooling down, is introduced through this flue, *l*, into a newly filled chamber until its temperature is brought up to 70° or 100° C. The moist air is then brought into contact with the freshly charged material, which acts as a condenser, and removes the moisture. The gas is then ready to be used. The radiation of heat, from the outside of this furnace, is, from its construction, very small. The control over the operations is perfect. The roof of every chamber contains several openings, which are closed with stoppers which are easily removed, so that the interior of the furnace can be inspected at any time. There is so little heat on the upper surface of the kiln, that it can be walked over, without any inconvenience. All the heat, remaining in the articles burned, may be used in heating the air, until the articles taken out are cool enough to handle. As seven chambers are ordinarily used in the full firing of one, two sets of firings may be going on at the same time, working in the same direction, with four chambers, or two to each set, being filled or discharged, or, if it is desirable, any one or two or more of a series may be skipped, if it is desirable or necessary. The temperature may be raised gradually or quickly, and maintained at a very high or a low heat for a long time, it only being necessary to increase or decrease the number of chambers behind, to raise or lower the temperature, and the number of the chambers in front to absorb the heat.

Any and every modification can be made to this kiln, that can be made to the ordinary intermittent furnace. It may be advisable, in many cases, either not to allow or only in a very restricted manner to permit the flame to come up through the floor of the chamber, as, for instance, in the case of such wares as are liable to

melt, and are, therefore, in danger of becoming soft and losing their shape in the last stages of the process, when the heat reaches them through direct contact of the flame. In such a case, the gas may be made to enter the corners of the chamber directly under the arch, and to have their exit over the whole floor of the chamber. This may be also the case in burning porcelain wares hard, when the temperature is so very high, and the saggers will hardly bear the direct contact of the flame. In other cases, when the chambers are very large, the construction shown in Figs. 4 and 5 is desirable, where the fire enters the chamber by the openings, *a*, Figs. 4 and 5, on both sides of the chamber just under the arch, and also by the openings, *b*, in the floor, while the excess passes out of the openings, *c*. By this method, the heat is not only increased, but made quite even over the whole chamber. The construction seems, at first sight, rather complicated, but, in reality, it is not much more so than in the ordinary construction of furnaces which are generally used for such kind of work.

The number of chambers, it is most advantageous to have in each one of these kilns, depends on the material which is to be burned in them, as well as upon the quantity of material which is to be manufactured in a given time. The following table gives the number and monthly product of chambers of ordinary size:

Articles burned.	No. of Chambers in the Kiln.	No. of Chambers burned per month.
Fire-bricks and red wares which are infusible,	14–16	24–36
Roof tiling,	16	29
Fusible red ware,	10–14	15–20
Clay pipes,	12–18	20–45
Unglazed stoneware,	16	50–55
Glazed stoneware,	16	70–80
Hard porcelain,	16–18	50–60
Dolomite,	12	40
Strontia and lime,	12	30–45

When the chambers are very large, they are burned more slowly than this, and, when they are very small, more rapidly. How rapidly it is to be done, must be determined, in every case, by the number of chambers that are to be built, and the quantity to be produced monthly. It has been found by experience, that the smallest cubical contents, which can be conveniently given to a single chamber, is 6 meters. It is quite possible, so far as the

working of the kiln is concerned, to make them as small as 4½ cubic meters, but they would be very inconvenient to charge and discharge. The largest that have as yet been built, have been 75 cubic meters. Above and below these two dimensions, it is doubtful whether the results would be satisfactory. The small ones are inconvenient to work in; the large ones answer perfectly well, but they require a constant and a very large output to make them economical. The number of chambers, that it is desirable to have for continuous working, depends on the kind of material that is to be burned in them. It is generally desirable to have between 12 and 14, but as many as 18 have been profitably used. Kilns with only 10 chambers have been built, where the articles burned require to remain for a very long time at high temperature, or when it is not necessary to be careful about rapidly cooling them, or when the materials to be treated in them, such as lime and dolomite, require no care in charging or discharging. It may not be desirable in some cases, at the outset, to go to the expense of building the whole of a furnace, such as could be used for continuous work, but only part of it, and to make the works intermittent. Such cases usually occur, when, either from want of funds or deficiency of market, or for any other reason, the present output of the kiln must be small, and when it is desirable to add to the plant little by little. In such cases, it will be sufficient to build only 6 to 8 chambers at first, and to construct them in such a way, that as many more can be added whenever it is necessary. It will be seen by the drawings that the number of chambers in any system of those kilns may, at any time, be diminished or increased to any extent, that it may be found desirable. When the number of chambers is small, say, 6 to 8, the kiln would, at first, be intermittent in its action, but could be made continuous whenever the additions to it were made. This is often the case with kilns for burning dolomite or lime. It is generally better, and, in the end, more economical when there is sufficient capital, to begin with a full-sized kiln and continuous working, as that not only gives the best results, but is, also, the most easily worked. It may sometimes happen in such a case that the output of the kiln is too large for present demand. In such a case, only that number of chambers may be used, which suffices for the present necessity, while the others may be temporarily cut off, and as much disconnected from the kiln as if they did not belong to the system.

I had occasion, at intervals of two years, to make a careful inspection of this furnace, as it was working at Hörde, burning dolomite for the basic process, and working so successfully that the cupola furnaces were never used for this purpose, except when the other work of the Mendheim furnace, in burning bricks for the use of the works, was so pressing, that it had more than it could do. The kiln at Hörde is composed of 16 chambers, as it is used mostly for burning the fire-bricks of the works. If it had been used only to burn the dolomite, 12 would have been quite sufficient. Each chamber of the kiln is charged with 11,500 kilos of raw dolomite, which is burned in 18 hours. 40 chambers per month are burned, which makes it possible to burn 460,000 kilos of raw dolomite per month. For every ton of coal used, 2550 kilos of raw dolomite are burned. Taking the loss in weight to be equal to 50 per cent., this would equal 1275 kilos of burned dolomite, or, in round numbers, 1300 kilos per ton of coal used. If fire-brick alone had been burned in this kiln, 14 chambers would have sufficed. If these had been very large, say, with a cubical contents of 63 cubic meters, 28 of them could be burned in a month. If they were small, say, 20 cubic meters, 40 might be burned in the same time. The quantity of coal required, depends on its quality, the size of the chambers, and the temperature required, and would be from 100 to 150 kilos for every 1000 kilos of finished wares, or, in mean, 125 kilos, which is about that found in actual practice.

In calculating the dimensions of a kiln, which is to work continuously and is to have specified dimensions, it is necessary to determine how many chambers shall be completely burned in a week. We will suppose that 2 are to be finished every 24 hours. If this kiln is to finish 84 cubic meters per week, then 14 chambers must have the capacity of 84 cubic meters, or each kiln, 6 cubic meters. It is hardly worth while to construct them smaller, as the difficulty of charging and discharging them increases very rapidly as they become smaller, as, when the workmen can no longer stand upright, the work becomes very fatiguing. When the cubic contents is, as in this case, fixed beforehand by the possible market for the wares, it would be better to diminish the number of chambers to be burned off in a day, which, at once, increases their capacity, but it should not be brought down to so small a number, that the kiln would be in danger of not working well. In any such case, where the dimensions of the furnace are to be

reduced to a minimum, the kiln should be constructed in such a way that it can be easily enlarged by building more chambers on to it, as soon as the demand for the material justifies it. It is always to be kept in mind that, with a very small number of chambers, the work must be intermittent, but that, with a large number, it need never be. The same useful effect of the fuel can never be attained in intermittent as in continuous working, because every time the kiln is put out of fire, the whole kiln gets cool. At least, the first chamber must then be heated by direct firing, so that there will be no saving of fuel; besides, the kiln having cooled down while idle, the other chambers must be heated up, so that, while the saving of fuel in continuous working, is at least 50 per cent., it will be reduced to 30 per cent., or even less, by such a process. Repairs to the different chambers are very seldom necessary, and can be made, when the furnace is working continuously, by shutting off that particular chamber that requires them, but when the number of chambers is small, and the kiln's working is intermittent, the whole kiln must be cooled down to make them.

A kiln, of 14 chambers, of 6 cubic meters capacity each, will, without the producer and chimney but including the gas-flues, occupy a space, 17 to 18 meters long, by 10 to 11 meters wide. It is always desirable to have both the producer and the chimney as near the kiln as possible. When, however, the kiln is constructed in a works already built, where there is a chimney which can be made to answer, it will generally be desirable to use it, even though the flue should be of some length, rather than to construct a special chimney. To economize the heat and save fuel, it is generally desirable to make the top of the kiln a drying-floor, which, in the coldest winters, will usually give out from radiation from the body of the furnace, and from the air which comes through the cooling-down chambers, which are no longer hot enough to heat the air for combustion, sufficient heat to dry the articles to be burned in the kiln. As this, however, materially increases the cost of the plant, it must, first, be carefully calculated, what advantage is to be derived from it, and whether the fuel saved warrants the expenditure. This is to be especially considered, where, in any case, drying stoves would have to be built, which would be heated directly. If there are no drying-stoves, then their erection would certainly cost as much as the drying-room over the kilns, and the question is easily settled, by calculating the comparative cost and efficiency

of both. If there are drying-stoves, the question will only be, what will it cost to use this heat, and what is it worth when it is saved? In any case, the kiln must be under a roof. Steps must be provided at both ends of it, so that access to the top of it will be easy, for the men must frequently go there to examine the working of any one of the chambers of the kiln, through openings made in the roof for the purpose, which are closed with slabs of fire-brick, when the chambers are working, and opened when it is in the last stages of cooling off.

The reason why it is desirable to have more rather than less chambers in a continuous kiln, is to prevent the workmen, in charging and discharging the furnace, being too much inconvenienced by the heat. The greater the number of chambers, the cooler the wares will be when finished, and the less likely the men will be to break them, from being obliged to handle them hot. The cubical contents of such chambers will, as we have seen, be determined by the weekly output which the whole kiln must have, and by the number which must be completely burned in the same time. When the heat must be as high as the melting point of cast-iron, there must be at least 10 chambers. If these chambers are to be turned every week, each one must have a capacity of 16 cubic meters; if only once in two weeks, a capacity of 8 cubic meters. It is thus the total number of cubic meters of material to be delivered in a given time, that determines the size of the chamber. To determine this, the maximum and minimum production are ascertained, and the mean taken, according as one or the other is most likely to predominate. This will generally be determined by whether it is or is not necessary to take special care of the wares when the chambers are cooling down, and to cool them very slowly. In such a case a minimum of production will result. In some cases, no special care is required in cooling, except that it shall be done slowly; in others, as in burning graphite crucibles, if unburned air is allowed to enter the kiln, the crucibles may be burned quite white on the outside from a partial combustion of the graphite, and as there is no means of ascertaining how much of the graphite has been burned, such crucibles are not considered as desirable as others, which have not been so affected. In such cases, great care must be exercised, to see that no unburned air enters the kiln. The cooling of this kiln takes place with very little risk to the articles being burned, as it takes place by the contact of hot air, whose temperature is grad-

ually diminishing, and no cold air comes in contact with the wares, until they are very near the temperature of the outside air, or, at least, so cool that there can be no possible danger from its contact.

Almost any fuel, which will furnish the requisite amount of gas, may be used for the producers, except the strongly caking blacksmith coals which are not suitable for making producer-gas. Very fine coals require the use of blast under the grate. Wet coals, especially peat, should be dried before using them, but when the quantity of water they contain rises beyond a certain amount, even when condensers are used, it is impossible to get a temperature sufficient to successfully burn articles which require a very high heat. When anthracite is used, it is generally desirable to introduce steam under the grate. It is usually desirable to sink the producer, so that the gas will rise into the kiln, and be used with as short a flue as practicable. Under such circumstances, there will be no necessity for down-takes, or iron pipes of any kind. All of the gas is delivered into the gas flues of the furnace. If the producers are properly constructed below ground, no disadvantage results to the men, and there is much gain in the working of the kiln. Experience has shown that it is desirable for the protection, both of the men and of the producer, to wall it in, and cover it with a roof, so that the men will be comfortable, and the producer-gas not be influenced by the action of the weather. When the kiln is a large one, only about 90 kilos of coals for 1000 kilos of material burned, are required. When, however, the kiln is a small one, or when the wares burned are very light and occupy a great deal of space, somewhat more fuel must be used to attain the same result.

As compared with the best of the intermittent furnaces the economy in fuel is 30 per cent. In comparison with the ordinary furnace, it varies from 50 to 70 per cent. The following tables* give the cost in fuel for 100 kilos of material burned, or per cubic meter of available room. In each case the carbon value of the fuel is compared with a free-burning coal of mean quality, the kind of wares that were burned being given in each case. All of those which are marked with a star refer to furnaces whose working was intermittent, all the others were continuous. This table shows very clearly, that the quantity of fuel to be used in each case, depends on the temperature which must be attained to

* Communicated by Mr. Mendheim.

produce the result, and that the kiln in this respect does not differ in any way from ordinary furnaces, except that the quantity to be used is, in each case, less with the gas furnace, down to the point where the fuels are so damp that it is no longer worth while to use them.

No.	Kind of wares and clay burned.	Mean quantity of fuel used per 100 kils. of material burned.				
		Lignite from	Kilos used	Coal from	Kilos used.	Reduced to coal.
1	Furrowed roof tiling,	.....	.....	Vicinity of the Saar,	14	14
2	Ordinary fire bricks burned red,	.....	.....	Upper Silesia,	10	10
3	Ordinary fire bricks, clay containing lime, burned yellow,	Styria,	20	.....	.....	10
4	Ordinary fire bricks, clay containing but little lime,	Saxony,	33	.....	.....	11
5	Ordinary fire bricks, clay containing but little lime,	Saxony,	31	.....	.....	10.3
6	Ordinary fire bricks, clay containing but little lime,	Brunswick,	31	.....	.....	10.3
7	Ordinary fire bricks, clay containing but little lime,	The Rhine provinces,	4.8	Westphalia,	11.5	13
8	Hard burned fire bricks, clay with little lime,	Saxony,	52	.....	.....	17.3
9	Hard burned fire bricks, clay with little lime,	Bohemia,	28.5	.....	.....	17.1
10	Paving bricks; clay rich in iron, poor in lime,	Bohemia,	25	.....	.....	15
11	Paving bricks; clay rich in iron, poor in lime,	Bohemia,	28	.....	.....	16.8
12	Paving bricks made of fire clay and a flux,	Bohemia,	21	.....	.....	12.6
13	Hard burned paving bricks, clay containing some lime,	Hard and soft wood,	21 8	.....	.....	13.1
14	Refractory wares,	.....	.....	Upper Silesia, south end,	14.7	14.7
15	Refractory wares,	Hessia,	31	.....	.....	12.4
16	Refractory wares,	.....	.....	Lower Silesia,	10	10
17	Refractory wares,	The Rhine provinces,	9.2	Westphalia,	9.7	12 7
18	Refractory wares,	.....	.....	Upper Silesia,	16.5	16.5
19	Refractory wares,	.....	.....	Vicinity of the Saar,	14	14

It is shown by the above table, that while ordinary fire-bricks, which must be evenly burned to produce a regular color, require from 10 to 11 per cent. of their weight in coal to do it; the amount of coal necessary when hard paving bricks are required rises to 12.6 to 16.8 per cent. of their weight. When hard fire-bricks, which must

be both uniform in texture and color, are required, the amount of coal will rise as high as 17.1 to 17.3 per cent., as these require to remain for a very long time at the highest temperature. When the wares to be burned are so light that their weight per cubic meter is very small, as grooved or furrowed roof-tiling, the amount of coal consumed, when calculated by the 100 kilos of burned tiles, increases; while the same wares, if calculated by the cubic meter of available space in the furnace, would show a less amount of fuel consumed. For burning fire-bricks generally about 12½ per cent. of coal is required. They will generally require more than hard-burned bricks, but not so very much more, as hard-burned bricks require, on account of the danger of their melting, a much more careful treatment, and longer burning, while ordinary refractory materials can be treated without a corresponding amount of care. The very great difference shown in the amount of coal used in Nos. 14 and 16, is owing partly to the difference in the calorific power of the fuels used, partly to the very high temperature required for burning the wares of No. 14, and partly to the differences in the sizes and construction of the two furnaces. In all kinds of brick wares, their weight is the best method of comparison, with the finer sort of wares especially, such as are burned in saggers, the effective capacity of the furnace is a much better method of comparison.

The fuel required, per effective cubic meter capacity of the furnace, is given in the table below:

No.	Kind of wares and clay burned.	Mean quantity of fuel used per cubic meter capacity of the furnace.				
		Lignite from	Kilos used.	Coal from	Kilos used.	Reduced to coal.
20	Pipes with a salt glazing,	Bohemia,	110	.....	.....	66
21	Biscuit stoneware,	.....	.....	Saar,	85	85
22	Biscuit stoneware,	.....	.....	Westphalia,	74	74
23	Smooth stoneware,	.....	.....	Westphalia,	50	50
24	Smooth and biscuit stoneware,	.....	.....	Upper Silesia,	62	62

In intermittent working as in kiln No. 18, which has only 6 chambers, and Nos. 19 and 24, each of which has 8, a much larger amount of fuel is used than for the same work in continuous kilns,

This is owing to the fact, that the flame which leaves the last chamber of the system, as well as the heat stored in the material which it contains, cannot be made use of; that the first chamber, at the commencement of every campaign, must be fired directly. For this reason, in such kilns, a fire-place is always built for the purpose, which is taken away when the kiln is made a continuous one, by the construction of the rest of the chambers, which are necessary to make a continuous kiln of it. This first chamber will always consume at least as much fuel as a good intermittent kiln. To this must be added the loss of heat and the waste of fuel which always takes place, in the producer, in the period between two burnings, although the producer is always kept full of coal, and all access of air is carefully shut off from it, notwithstanding which, it has been constantly shown by practical experience, that an intermittent furnace of this type, works in any case, both cheaper and better than an ordinary furnace, and that it will, therefore, often be worth while to build an intermittent furnace of this type, with the expectation of adding to it at some future time. Nos. 8 and 14 are excellent examples of the use of a very inferior fuel, to attain a much higher temperature than had hitherto been attainable in intermittent furnaces. With the fine Silesian coal, a blast at considerable pressure had to be used in the producer. This it is desirable to do, when lignite is used, which is either not sized at all, is full of dust, or is very fine. For almost every kind of work, these furnaces can be so managed, that no smoke at all is ever given off by the chimney. In exceptional cases smoke is sometimes made, but in such small quantities as to be of no consequence.

It is not quite as easy to compare the quality of the work done, as the quantity of fuel which is used in the ordinary intermittent, and the constantly working furnace. One of the first things which makes the gas furnace, whether intermittent or not, superior to the furnace with direct firing, is the entire avoidance of ashes, which are always carried over with the flame in the direct furnace, and which are never found in gas furnaces. In the case of fire-bricks, terra-cotta ware, and paving bricks, these become attached to, and deface the surface of the wares, and they must, therefore, be protected in the ordinary furnace, by the erection of shields, which catch the ashes, and prevent their falling into the wares. This is especially true of pipes, and such other materials as are glazed,

for the ashes sticking to the surface of the glaze, would produce a very unsightly appearance. When fire-bricks are burned directly in furnaces of ordinary construction, there is a loss amounting to not far from 10 per cent. of wares, which must be thrown away on account of the melting of the surface, owing to the deposit of ash carried over by the flame. Another advantage is, the ease and certainty with which the furnace can be regulated to a temperature required for any given ware. As when, for instance, it is desirable to produce different but distinct tones of color in different fire-bricks of the same quality, one of which requires a flame composed mostly of gas; in the other, one with a very large admixture of air, as when materials made of glass, containing a considerable quantity of lead, are burned. It is true that exactly the same may be done in other furnaces, but in gas furnaces it can be done much more easily, and with greater certainty. The same is true in the burning of fire-bricks, when a yellow brick, of even tint, is made from a marl which melts easily. In general, it may be said, that with these furnaces the manufacturer is less dependent on the men, and that the responsibility is much more direct, and much more easily particularized, than with other furnaces. Any damage which might arise, from too quickly raising or lowering the temperature, is much more easily avoided, principally because the heat comes, in the first instance, from wares which are cooling down, and the cooling takes place progressively, so that in neither case is very hot or very cold air brought in contact with the wares, at the last nor at the first. This is especially remarkable in the burning of large pieces of terra-cotta wares, and articles made from either fat, or short clay, and in the longer time the saggers, in which porcelain stonewares and such material are burned, will last. Such saggers can be used from two to three times as long, as in an ordinary furnace, in which cold air must be allowed to enter to shorten the time of cooling down. The repairs to such furnaces will also be less for the same output, principally because they are heated and cooled more regularly, but also because the ashes do not become attached to the surface of the walls so as to cause them to melt.

Muffle furnaces are constructed on the same principle, and are used when the gases must be kept entirely away from the materials, so that they are always surrounded only by heated air, which is always necessary where gold or colors are to be burned into

glass, or on to the glazing of porcelain or stoneware, or for burning the glazing on to majolica wares. For all of these cases a continuous gas muffle is most serviceable. For glass decoration or for glazing, the best number of muffles to use is from 12 to 14. The quantity that such a kiln can produce depends, of course, on the size of each muffle, and may be very large. The time that each muffle requires to burn, depends on its cubic capacity. It must be counted that it will take from 3 to 3½ hours to burn 5 cubic meters, so that for stoneware, more than 50 muffles a week can be burned. With hard porcelain the number will be somewhat less. The quantity of coal, just as it comes from the mine, that is required for a muffle containing 5 c. m., is about 440 kilos or 88 kilos per cubic meter, whereas the non-continuous muffles require from 1300 to 1400 kilos, or 260 to 280 per cubic meter of muffle, which is a saving of two-thirds of the coal, or in the case of a somewhat large production of stoneware, 22,000,000 kilos of coal, or a saving of 22,000 marks. This saving is so large, as to easily compensate for the greater cost of the gas muffles, in a few months' use, in a large works. For burning colored glazings on majolica ware, a longer time is required or from five to six hours, and a consumption of coal of 195 kilos per cubic meter of muffle. On account of the longer time it takes to burn them, 10 muffles are sufficient for continuous working, and 30 muffles a week can be burned. In the ordinary non-continuous muffles the amount of coal used and the time of burning is three times that of a muffle furnace. If the burning could be done in ordinary furnaces it would be about 37 per cent. cheaper, but there is such very great danger of damage to the large pieces in such furnaces that it has prevented them from being used. This danger is entirely avoided by the use of muffles. With regard to uniformity of temperature, durability of the muffles and walls, there is no comparison to be made between the ordinary and the gas muffle, which is owing to the way it is heated up and cooled. Muffles of much smaller size can be used in continuous work when a less output is required, and their working can also be often suspended without any greater disadvantage than an increased expense in fuel. When such non-continuous work is done, it is well to see that at least four to five muffles are burned together, and not that one muffle should be burned one day and another the next, as by such a system, more fuel would be burned than in an ordinary non-continuous furnace.

It may often happen that it is undesirable to burn the muffles during twenty-four hours, and that it is desirable to burn them during the day only, or that on one day more, or on another day less muffles, should be burned, and on some days none at all. In such a case it is desirable to erect only four to six muffles, the first of which should be fired in the morning and the last burned in the evening, or night. The following practice, taken from actual work, may in that case be followed. This furnace was erected for tempering pressed ware, which requires only a low temperature, much lower than for decoration. It consisted of five muffles of 2.2 cubic meters capacity. The first of these was charged in the morning and fired the next day. During the time it was in fire, the muffles which had been previously burned were discharged and filled, and then burned. The time of burning of the first muffle was three hours and thirty-five minutes; the other four muffles together eight hours and twenty minutes. The cost of the coal, not including 30 pfennigs' worth of wood to light it, was:

For the muffle,	I.	II.	III.	IV.	V.
In coal.	346	251	226	206	139
Per cubic meter of muffle,	158	114	103	94	63

Or in mean, 106.4 kilos per cubic meter of muffle. The time for burning all the five muffles was eleven hours and fifty-five minutes. If decorated ware had been heated, the time would have been sixteen to eighteen hours, so that even in that case the fireman would have had the night to rest. Smaller muffles would take proportionately less time. It thus appears that the gas muffle system, even for small decorations and often changing work, can be used to very great advantage, and that the very small inconveniences which they have are hardly worth notice.

The following tables* give the cost of construction of five furnaces of different capacities constructed for different purposes in different countries.

I.

Cost, in German marks, of the erection of a 14-chamber kiln, each chamber having 8.13 cubic meters capacity, with two shaft-producers of 3.4 square meters surface at the belly, but without including the cost of the chimney:

* Communicated by Mr. Mendheim.

	Marks.
Foundations in stone, at 5.75 m. the c. m.,	2241.92
Labor of construction,	3882.00
Red brick, at 25 marks the M.,	2343.00
Chamotte stone (fire-brick), 3 to 4.50 marks the 100 k.,	7500.00
Paving,	330.00
Iron work,	2574.00
Sundries,	800.00
	19,670.92

The cost of labor was—

	Marks.
Head mason, per hour,	0.40
Bricklayers, per hour,	0.24
Laborers, per hour,	0.19

II.

Cost of a 16-chamber kiln, each chamber being of 16.5 c. m. capacity, with 2 step grate producers with fire-grate 2 m. wide, designed for high temperatures. The chimney is not included:

	Marks.
Chamotte bricks, 1st quality, 90,000 k. at 2 m. the 100 k.,	1800.00
" 2d " 671,775 k. at 1.60 m. the 100 k.,	10,748.40
Ordinary brick, 22 m. the M.,	2987.00
Chamotte mortar, 109.700 k. at 2 m. the 100 k.,	2194.00
Lime mortar,	272.00
Cement,	90.00
Loam mortar,	75.00
Cast iron,	3068.76
Construction and lifts,	333.65
Old iron for foundation, old rails, etc., 80 m. at 3 m.,	240.00
I beams, 4602 k. at 12.5 m. the 100 k.,	575.25
Round iron, 244.8 meters at 2 m.,	489.60
Digging out foundations,	622.50
Sand for filling,	76.00
Kiln floor,	78.00
Masons and laborers,	6566.27
	30,169.43

III.

Cost of a kiln with 10 chambers of 33 c. m. with 2 producers using wood, not including the chimney. As few fire-bricks as possible were used on account of their high price; this furnace was built in Russia for the manufacture of hard-burned paving stones.

	Marks.
980 c. m. of excavation at 0.075 m.,	73 50
351.6 M. adobes, 23 × 11.5 × 6 c. m., at 3.50 m.,	1230.60
70.2 M. chamotte bricks, at 3.75 m. the M.,	2632 50
351.6 M. of special adobes, at 2.25 m.,	791.10
70.2 M. of special chamotte bricks, at 2.70 m.,	189.55
24,570 k. of fire-clay mortar, at 1.6 m. the 100 kil.,	245.70
8000 k. of old iron rails, at 2 m. the 100 k.,	160.00
3750 k. of round and square wrought iron, at 12.485 m. the 100 kil.,	468.18
10,480 of special wrought iron, at 8.44 m. the 100 kil.,	883.98
8 brick elevators at 3 m.,	24.00
20 m. of water pipes for cooling, at 0.65 m.,	13.00
Sundries,	37.89
	6750.00

Two wood gas producers:

349 c. m. of excavation, at 0.075 m.,	26.17
50 M. adobes, at 3.50 m. the M.,	175.00
5 M. chamotte bricks, at 37.50 m. the M.,	187.50
50 M. of special adobes, at 2.25 m. the M.,	112.50
5 M. of special chamotte bricks, at 2.70 m. the M.,	13.50
2000 k. of fire-clay mortar, at 1 m.,	20.00
	534.67
3450 k. of cast iron for doors, valves, etc., at 8.43 m. the 100 k.,	291.00
4000 k. cast iron for fire-place, at 6 m. the 100 k.,	240.00
19,000 k. of old iron rails, at 2 m. the 100 k.,	38.00
750 round iron for braces, at 12.48 m. the 100 k.,	93.63
Sundries,	2.63
	1200.00

Cost of furnace,	6750.00	
Cost of producer,	1200.00	
	7950.00	

IV.

Cost of furnace with 16 chambers of 46 c. m., not including the chimney:

	Marks.
Excavation of 1500 c. m. of earth, at 0.50 m.,	750.00
Filling in 334 c. m. of earth, at 0.50 m.,	167.00
197.4 M. ordinary bricks, at 20 marks the M.,	3980.00
349 M. shape bricks, at 35 marks the M.,	12,215.00
101.8 M. chamotte, second quality, at 55 m. the M.,	5599.00
10.2 M. chamotte, first quality, at 70 m. the M.,	714.00
2500 k. chamotte, at 12 marks the 100 k.,	300.00
100,000 k. fire-clay, ground fine, at 1.40 m. the 100 k.,	1400.00
145,000 k. of fire sand and clay, at 0.40 m. the 100 k.,	580.00

461 M. white and fire-bricks, at 18 marks,	8298.00
197.4 ordinary bricks, at 15 marks the M.,	2961.00
222 running meters of old rails, at 3.00 marks,	666.00
8470 k. of round iron, 40 mm. in diameter, at 30 marks the 100 k.,	2622.00
13,500 k. of cast iron, at 15 marks the 100 k.,	4050.00
Sundries,	1730.00
	46,000.00

Three step grate-producers with grates 2 m. wide:

	Marks.
300 c. m. excavation, at 0.50 marks the cubic meter,	150.00
30 c. m. of filling material, at 0.50 marks the cubic meter,	15.00
15.7 M. bricks, at 20 marks the M.,	314.00
24 M. white bricks, at 35 marks the M.,	840.00
19 M. fire-bricks, 2d quality, at 55 marks the M.,	1045.00
10,000 k. ground chamotte, at 1.40 marks the 100 k.,	140.00
9000 k. fire-clay, at 0.40 marks the 100 k.,	36 00
48 M. of white and fire-bricks, at 18 marks the 100 k.,	864.00
145 M. red bricks, at 15 marks the M.,	217.00
60 meters old iron rails, at 3 marks,	180.00
90 k. iron, 40 mm. in diameter, at 30 marks the 100 k.,	27.00
6000 k. of cast iron, at 24 marks the 100 k.,	1440.00
Sundries,	557.00
	6000.00

	Marks.
Cost of the furnace,	46,000
Cost of 3 producers,	6,000
Total cost,	52,000

V.

Cost of a kiln with 14 chambers of 65 c. m. each, built for making fire-brick and other refractory wares and intended for very high heats.

	Marks.
1710 c. m. of excavation, at 0.50 marks the cubic meter,	855.00
275 c. m. of refilling, at 0.50 marks the cubic meter,	137.50
450 M. bricks, at 14.75 marks the M.,	5900.00
300 M. fire-brick, at 45 marks the M.,	14850.00
240 M. burned bricks, at 26.5 marks the M.,	6360.00
153,200 k. of mortar of 1st quality, at 1.50 m. the 100 k.,	2298.00
120,000 k. of mortar of 2d quality, at 0.80 m. the 100 k.,	960.00
83 c. m. of loam for mortar, at 0.75 marks the c. m.,	62.25
167 c. m. of sand for mortar, at 0.75 marks the c. m.,	125.25
10,000 k. of cast-iron valves, at 15 marks the 100 k.,	1500.00
3200 k. of cast-iron covers, at 13 m. the 100 k.,	416.00
8850 k. of old iron rails, at 10 m. the 100 k.,	885.00

Egleston.

HE

EIM FURNACE.

tion.

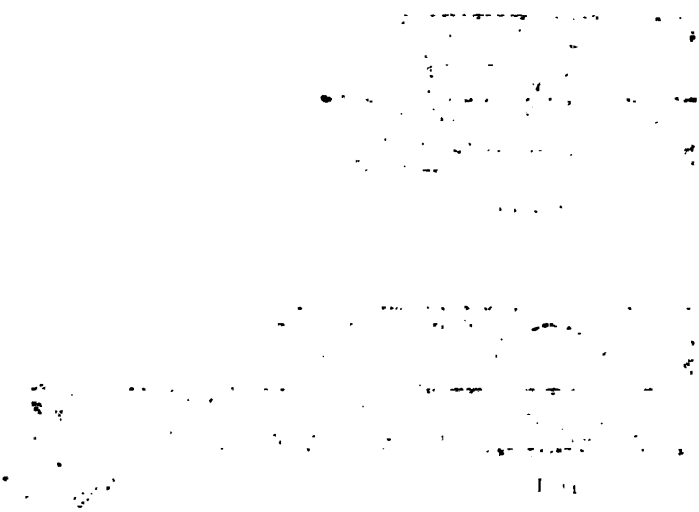
Fig. 4.

Cross Section.

Fig. 5.

Plan.

FIG. 1.



5300 k. round iron for braces, at 20 marks the 100 k.,	1060.50
120 k. 1 mm. sheet iron, at 30 marks the 100 k.,	36.50
100 k. of nuts and bolts, at 50 marks the 100 k.,	50.00
4 levers, at 50 marks,	200.00
2 pulley-blocks, at 20 marks,	40.00
365 c. m. ashes for filling, at 3 m.,	1095.00
400 M. common bricks, at 15 marks the M.,	6000.00
570 fire-brick, at 18 marks,	10,260.00
Sundries,	910.00
	54,000.00

Four step grate-producers for caking coal, each 2 m. wide.

	Marks.
550 c. m. excavation, at 0.50 marks the c. m.,	275.00
100 c. m. of refilling, at 0.50 marks the c. m.,	55.00
40 M. common bricks, at 14.75 marks the M.,	590.00
10.5 M. fire-brick, at 45 marks,	472.50
12 M. burnt bricks, at 26.50 meters,	318.00
50.000 k. fire-brick mortar, 1st quality, at 1.50 marks the 100 k.,	75.00
6000 k. fire-brick mortar, 2d quality, at 0.80 marks the 100 k.,	48.00
17 c. m. of sand for mortar, at 0.75 marks the c. m.,	12.75
7 c. m. of loam for mortar, at 0.75 marks the c. m.,	5.25
3 tons of lime, at 3.65 marks the ton,	10.95
7760 k. of cast iron for the fire-place, at 13 marks the 100 k.,	1008.80
2540 k. of cast iron for valves and hoppers, at 15 m. the 100 k.,	380.00
2475 k. of old iron rails, at 10 m. the 100 k.,	247.00
550 k. iron parapet for producer, at 25 marks the 100 k.,	137.50
420 k. round iron for braces, at 20 marks the 100 k.,	84.00
125 k. of chains for hoppers and valves, at 60 m. the 100 k.,	75.00
175 k. pokers of wrought iron, at 50 marks the 100 k.,	87.00
1 steps from the ash-pit,	48.00
10 c. m. of ash filling, at 3 marks the c. m.,	30.00
40 M. common bricks, at 15 marks the M.,	600.00
22.5 M. fire-brick, at 18 marks,	405.00
Sundries,	33.25
	5000.00

	Marks.
Cost of the furnace,	54,000
Cost of the producers,	5,000
Total cost,	59,000

It is not worth while to use this kiln for burning ordinary brick, but for all wares, such as porcelain, fire-bricks or material which must resist a high temperature, or for delicate articles which must be carefully burned and cooled, it is one of the very best. As well gas retorts of the largest size, as articles which have a very

small weight, to the cubic meter of space occupied, can be burned with the best results. It is especially adapted to the burning of such wares as crucibles, which must be burned not only with care, but with a certain quality as well as quantity of heat. It is adapted to the manufacture of all kinds of crockery wares, but can be just as advantageously used in burning tea-cups as the largest gas retort.

NOTES ON RAILWAY BLOCK SIGNALS.

BY F. R. HUTTON, SCHOOL OF MINES, NEW YORK.

NEGLECTING the disasters from cyclone, earthquake, flood and the other elemental convulsions, beyond control of men, for purposes of study the costly accidents in railroading may be classified under four heads.

I. ACCIDENTS TO ROLLING STOCK AND MACHINERY.

These can only be guarded against by most careful inspection and by the rigid condemnation, after a certain length of service, of parts subjected to shock and fatigue. Even then, breakage will occur, in spite of every precaution, and the administration of the road can hardly be held solely responsible.

II. ACCIDENTS DUE TO A BREAK IN THE CONTINUITY OF THE TRACK.

These can be subdivided considerably to take account of the varying causes for that broken track. Bridge and trestle disasters come from decay, fatigue, corrosion or faulty design, or they may be caused by some of the other and lesser accidents happening on the bridge or trestle. Derailments come from spreading of track, breakage of rails, bad surfacing in relation to speed, malicious or accidental obstructions on the track, and by misplaced switches. Or, again, at washouts and at open drawbridge spans, the train may find its track non-continuous, and hence an accident may result. The safeguard against these accidents is again the most careful inspection and "policing" of the permanent way, in conjunction with a proper and interlocking system of signals.

III. Collisions of Trains.

These may occur "head on" to two trains in motion on the same track in opposite ways. A rear collision occurs when one train runs into the rear car of another, the front train either standing on a track, or running at less speed than the colliding train. A collision may also happen when an accident on one track has thrown wreckage upon the other track of a double-track road, and also, when, by a misplaced switch, a moving train on the main line runs into another train or cars on a siding. And, lastly, at a crossing, either acute or obtuse, there may be cars standing or running across the path of the colliding train. There may be also classed with collisions any accidents to teams at grade-crossings of highways. Train collisions can be guarded against by proper system of administration with respect to train orders to the crews, coöperating with a system of interlocking and defensive signals. It is to these latter signals that attention is to be called in this paper.

A fourth class of accidents, which may occur in connection with either of the last two classes, is the disregard or misunderstanding by the train crews of orders or signals given to them. This is a failing case, however, for which usually one man is distinctly to blame, and as he is, as usually, the engine-runner of the train, he has the strongest possible inducement to make no mistake. Similarly conflicting orders can only be given to the trains by a pronounced failure in the mental capacity of the one person entitled to give them, and it seems difficult by any foresight or administrative system as such, to prevent accidents of this fourth class.

What is known as the interlocking system of switches and signals, whether in some of its elementary or more complex forms, will furnish a safeguard against switch and drawbridge accidents, always under the limitations of the fourth class. To guard against collisions, front and rear, on single and double track, is the object of what is known as the block system.

Block systems are of two kinds: The time-block and the distance-block. The time-block system is based on the principle that no two trains shall pass a given point within a definite interval of time, usually five minutes for passenger trains. This postulates that the first train shall not stop for five minutes between indicators, nor slacken speed, nor must the first train shed any of its

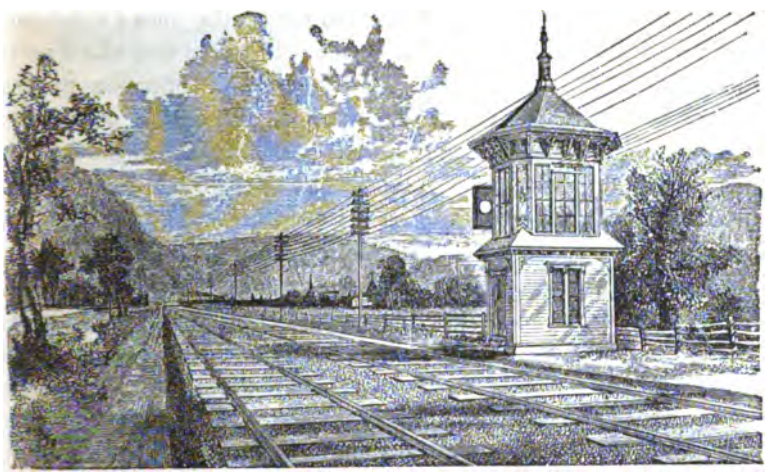
rear cars. In the last of these cases, of course, the second train will only be prevented from collision by the outlook forward of its engineer: in the first case, of stoppage, the fidelity of the rear brakeman in running back with a flag must be depended upon. This system may be combined with the other; as, for instance, on the N. Y., N. H. and H. R.R., where the station-masters set up upon a time-board the hour at which the last train went by in each direction. The knowledge which the engine-runners thus receive gives added certainty to the correctness of the distance-block signals.

The distance-block system intends, that no two trains shall be within a certain distance of each other. There are two general types: The automatic and the non-automatic. The Pennsylvania Railroad gives, perhaps, the best example of the non-automatic type, and its system is briefly as follows: The line is divided into sections or blocks of varying length, shorter in proportion to the number of trains. At the beginning of each block is a signal-cabin, with a telegraph operator, in communication with the cabins on each side of him. He receives from the operator on one side of him word that, at such an hour, a certain train, designated by its table number, has passed him, with a certain number of cars. When that train has passed his cabin, he telegraphs back to operator No. 1 that the train of designated number has passed him with a certain number of cars, and if that number agrees with the memorandum in the hands of No. 1, the latter, who has displayed a red signal to block all succeeding trains, moves his signal from red to white, showing the block clear. Meanwhile, the operator in the middle cabin displays his red signal, and notifies No. 3 of the passage of the train. The red signal is kept displayed until the train and all its cars have passed No. 3, who so informs his comrade in the previous block. No two passenger trains are allowed on the same block. Two freight trains are allowed, the latter coming on under a green signal, to impose caution and careful running.

The failing case of this system is the result of the negligence of the operator, to which cold, sleep and overwork are contributing causes. The system requires also a double set of operatives for day and night work, and the expense of the instruments and cabins is considerable. The figure shows one of the signal-cabins of the Pennsylvania Railroad.

To give additional safety by guarding against this failure, the system has been modified by combining with it the principles of electric interlocking. That is, it is made impossible for operator No. 1 to withdraw the red signal after he has displayed it, until a detent is withdrawn by the excitation of an electro-magnet, the control of whose circuit is in the hands of operator No. 2 at the further end of the block. To open the block to a second train requires by this system the concurrent negligence or criminality of two operators, which it is more than twice as difficult to secure. Or, again, the movement of the signal at cabin No. 2 from danger to safety is put entirely out of the control of operator No. 2, but is

FIG. 1.



done entirely by electric means operated from No. 3. These latter methods are more in use abroad, and but to a very limited degree in this country.

In the automatic block systems, the operators are dispensed with, with the cost of their labor and their cabins. The signals are operated by the trains themselves, electricity being a necessary adjunct. There are two general types of this system which present marked differences. In one system, the train closes an open electric circuit, excites the magnet at the signal, and pulls up the red disk. In the other system, the train acts to cut out the signal by "short-circuiting" the current, and the signal drops to danger. The decided advantage of the second system is that any failure of

the electric current sets the signals to danger. The apparatus thus gives warning of its own shortcomings, whereas in the other system, when the current failed, the train would not be protected, because the signal remained at safety when no current was passing.

A second difference consists in the use by the second system of the rails as conductors for the signal currents. The first system carries its circuit on special wires. The current in the rail system passes along one rail of a block, through the signal which it holds at safety, and back through the other rail. The successive block sections are insulated from each other by rubber gaskets and washers, and the contiguous rails in each block are connected together by telegraph wire secured to the foot of each. This is a safeguard against defective electric contact from rust or looseness at the fish-joint. If, now, a single pair of wheels on an axle rests anywhere upon the block, the current will pass from the line to the gauge rail through the axle, and the current will cease to flow through the signal and it will show danger. If a train sheds a car on the block, the signal cannot go back to safety; if a rail is taken up, or the track washed out, and the current broken, the danger signal appears. The opening of a switch or a draw-span can be made to set the block signal to danger, and it makes no difference from which direction the car comes which closes that block. A hand-car, belonging to the track-gang, or one of their bars gives a protection to them in their labor by short-circuiting the block signal, and setting it to danger at the beginning of the section. The current finds so easy a passage on the conductors of large surface, that the leakage and grounding, caused by snow and water, is inconsiderable. A single cell of a gravity battery will furnish current for a mile of track.

A third difference between the different systems consists in the choice of a weight to move the signal when an electric detent is released, as contrasted with the plan of giving such size to the electro-magnets and such electro-motive force to the current as to make the attractive force of the magnet operate the signal. The advantages are in favor of the mechanical system, since less battery power is required, and there is no variation in the force which moves the signal. In one of the plans it is made impossible to attach and detach the night-lamp without winding up the clock-work, and provision is made to have the signal show red when the

mechanism is run down. The clock-work is made to operate for at least 350 trains before this happens.

In the wire systems, there has to be a track-instrument, or track-treadle as it is sometimes called, by which the passage of a track shall make an electric contact at the signal. These are of several forms. The simplest consists of two metallic pads situated in a rubber casing under the rail; one pad is connected with the positive wire, and the other to the negative (Fig. 3). The deflection

FIG. 2.

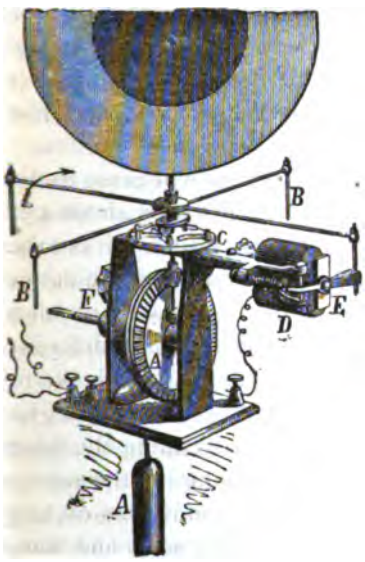
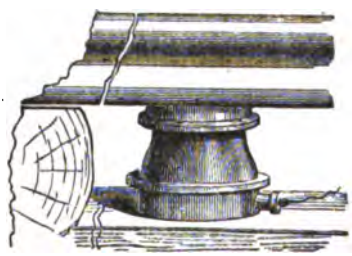


FIG. 3.



of the rail by the passage of the engine-drivers, brings these two pads together, and closes the circuit. The other form of track-instrument, first brought out in connection with the Hall system, consists of a hollow, cast-iron post at the side of the track, from which a lever or treadle extends, and lies close to the rail. A rubber spring holds this treadle so that, when no wheels are passing, its rail end projects above the plane of the tops of the rails. The passage of a pair of wheels depresses this treadle, and lifts the further end inside of the post. This rise of the outer end forces up a rod in the post, and makes a closure of the circuit. Now, some means must be provided to prevent a succession of electric impulses being imparted to the signal magnets. This may be done

either by making a cataract attachment in the hollow post, whereby the rod is prevented from falling to break the circuit any faster than the escape of air through an adjusted outlet will permit, or else the signal is so made that, just as it swings to danger, it breaks the circuit which has just actuated it. This is a feature of the Rousseau system, as shown at C, Fig. 2. At the end of the block is another instrument which reverses the action caused by the first instrument, and the signal goes to safety. The signals themselves are usually disks of bunting stretched on a wire-frame, which are shown in front of a glass window in a closed case, the latter large enough to conceal the disk, and leave the window clear when at safety. In some of them, the red disk rotates on one diameter through 90°, showing its edge only at the window when at safety. A lamp behind the window is attached at night, and shines through the window and the disk.

A feature of several of the systems, which has been borrowed from English practice, is the use of what are known as "home" and "distant" signals. In single-track block systems, it is desirable to inform the runners of trains, not only about the block on which they are entering, but also about the succeeding one, and the names which are used, suggest their connection. Or, again, sometimes complementary signals are used, the second or safety signal being of a blue color, and operated by the action of the primary danger or red block signal. In this case, the blue signal is placed some distance behind the red signal, and is always in the position which the red signal is not. It, therefore, assures the engineer, when he has passed upon the block, that he has been protected by the red signal, if he finds the blue signal invisible. If the blue signal is displayed, he knows that the red block signal has not acted, and he is exposed at the rear.

It is, moreover, possible by combining the rail-system of conductors for the home signals, and the wire-system for the distant signals, to enable runners on a single track to follow the motion of trains on the block in front of them. It would, perhaps, be unprofitable to follow this into detail, but, in a general way, the succession of the changes in the signals shows whether a train is approaching or receding from the observer.

No attempt has been made in this article to enter into the mechanical and electrical details of the construction of the signals themselves. To do so, would be to transcend the scope of this

discussion. The object has been simply to note the problems which are to be met, and to outline the degree of success which has attended the attempts at their solution. The fascinating field of the interlocking systems of signals, of course, is also a separate specialty, and is entitled to study by itself.

SOME OLD GOLD MILLS.

BY F. N. HOLBROOK.

WHILE on a professional trip to South America some time since, I came across a large number of small gold mills, a description of which may prove interesting. These mills probably saw their last service during the first century of Spanish rule, and many millions of dollars are reported to have been extracted from the gold bearing rock of the mine around and near which they were found.

The country traversed in order to reach the mining district I wished to examine, had been at one time, according to tradition and to such evidences as were found along our road in the shape of ruins, well populated. At short intervals sites of once prosperous villages were found, each being marked by the remains of huts, or a chapel; and now and then the lemon and other fruit trees clustered together, probably occupying the space formerly set apart as the family orchard.

On either side of our path was a dense tropical forest, a mass of tangled luxuriant growth, frequently requiring the use of the natives' heavy machéte to clear the way. On reaching the principal mine, evidences of the great work that had been done were seen on every hand. The vein had probably been worked at intervals for over 3000 feet of its length, mainly by open cuts.

The sides of the cuts were covered with a luxuriant vegetation, with here and there a tree measuring two or three feet in diameter growing up from the bottom, denoting the long absence of the workmen who with great labor had excavated them. Several of the cuts measured 150 to 200 feet in depth in some parts, and one was over 1000 feet in length. The vein was of considerable width,

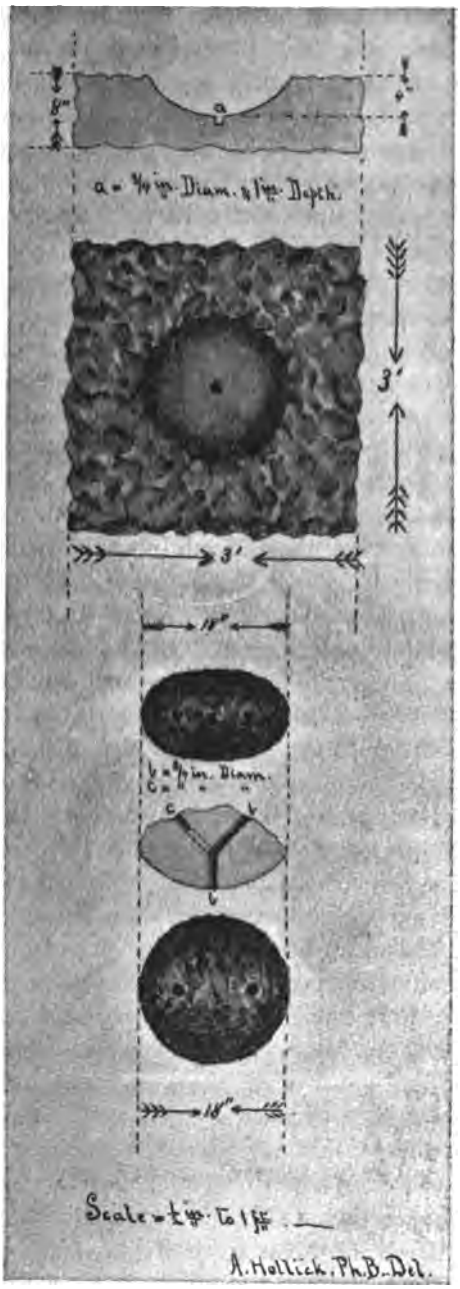
averaging 18 feet, and consisted of a very much decomposed quartz carrying free gold.

Much of the quartz was soft enough to be taken out with the pick, and all could be broken down with hammer and gads. The enclosing or country rock was a dark-colored porphyry very much decomposed for a considerable depth below the surface. In looking about to determine where the great mass of ore taken from the mine had been worked, and finding no signs of the use of the arrastra or Chilean mill, I had about concluded that the ore had been transported to some other point for reduction, when my attention was called to some stone walls built along the edge of a stream and almost hidden by the dense foliage. On closer examination I found a terrace had been built along either side of the little stream, on which were a number of small stone mills, and on looking still further thereabouts, found that every little stream and spring had been the scene of great activity. A hundred or more of these small mills were encountered in the immediate vicinity of the mine.

Each mill consisted of a block of the hard, undecomposed country rock about three feet square and varying in thickness from eight inches to three feet. In the upper side a basin as shown in the drawings, was made, varying in diameter from eighteen inches to two feet, and having a depth at the centre of about four inches.

In the centre of the bottom of the basin a hole from three-fourths to one inch in diameter, and about one inch in depth was drilled. Two kinds of mullers or grinders were made to work in the basin, one of which was elliptical when shown in plan, the other circular. The under side of both, however, was trimmed and ground to fit the curve of the basin. Into each muller on the upper side were drilled one and sometimes two holes, as shown in the section; in case of only one hole being bored it was carried through to the under side as shown by "b, b," and if two were drilled only one was carried through as shown in the drawing. The hole thus drilled was made to open directly over the hole "a" in the bottom of the basin when the muller was placed in position for grinding. We may suppose that in order to work the muller with more ease a wooden handle was inserted in one of the top holes as an aid in turning it.

From native description and example as shown me, the probable working of the mill was somewhat as follows: The ore after


a = ½ in. Diam. ½ in. Deep.
3'
3'
18"
b = ½ in. Diam.
c = " " "
18"
Scale = 1 in. to 1 ft.
A. Hollick, Ph.B. Del.

being broken quite fine by hammers was fed in small quantities into the basin with some water. Then by alternate rocking and turning round of the muller the ore was soon reduced to a fine state of division. At intervals water was added through the hole in the muller. This would cause an upward current in the basin carrying some of the finer materials up with it, and so separating the particles, that the gold which had been freed from its matrix would readily settle towards the centre, and gradually concentrate in the hole in the bottom of the basin, where from time to time it might be gathered.

I question very much whether quicksilver was ever used in the process, as it would not have served any more effectually in collecting the gold than did the hole in the bottom of the basin. The average of all the ore extracted did not exceed $7.00 or $8.00 per ton, with perhaps now and then a rich chimney or ore body being encountered which would raise the value to $30.00 or $40.00 per ton for a while.

The enormous amount of work accomplished by these old workers, with the tools and machinery at hand in those days, would be surprising to one acquainted only with modern inventions, but when we are told that it was during the days of Spanish rule that the work was performed, we have the whole explanation. With Indians and negroes as slaves, and a country which produces everything in wild profusion for the maintenance of life, we can easily see how a mine could be made to pay, and handsomely too, worked by such simple methods.

LINE OF ORIGIN OF THE CHARLESTON EARTHQUAKE.

BY EMIL STAREK.

PRELIMINARY DETERMINATION.

THE agents concerned in volcanic action have figured as important factors in the geological history of the globe, and have been productive of many prominent terrestrial features. Earthquakes are attributed to "pressure caused by previous conditions con-

nected with mountain making in that part of the sphere,"* and, in volcanic regions, to the tension of confined vapors, their sudden evolution, and, locally, to undermining of the country rock, etc., but it must be admitted, considering that our acquaintance with earthquakes dates back as far, perhaps, as history itself, that the facts in regard to them have never been sufficiently systematized and coördinated to justify us in the claim of having established a new science. Indeed, what progress in seismology has been made is within the last twenty-five years; and the late Charleston earthquake will add, to the meagre knowledge we now possess, additional material for collation and digestion.

A few facts in regard to this earthquake have been published in *Science*, and other scientific periodicals, and the object of the present communication is to contribute one of the results of an investigation based upon the most reliable time data and intensity reports from some of the localities in the regions most seriously affected by the shock of August 31. It is the determination of the "line of origin" of the earthquake by the process known as the "method of coördinates"—the analytic expression for the position of a point referred to the intersection of three *coördinate planes.*

Though the data now on hand will not permit us to assert the true cause of the earthquake, we are safe in supposing that the shock did not originate at a point, but along a line more or less curved, and the general direction of which is N.E. to S.W. It will be interesting to note that the line obtained by this method coincides pretty well in direction and position with the line of the Piedmont escarpment.

The method used, although properly applicable to cases where the origin is a point, serves to solve the problem under consideration, as it gives us a number of points, which, when joined by a line, give us an open curve along which the time of disturbance was simultaneous.

To illustrate the manner in which the result was obtained, I shall first describe the method of coördinates as given by Milne. Let us assume five places which the shock reached at different times. Beginning with the place that the shock reached last; call these

* Dana's Manual of Geology, 3d ed., p. 804.

places p, p_1, p_2, p_3, and p_4, and let the times taken to reach these places from the origin be t, t_1, t_2, t_3, and t_4. Through p draw rectangular axis, measuring with proper scale the coördinates of p_1, p_2, p_3, and p_4, and represent these by $x_1\ y_1$, $x_2\ y_2$, $x_3\ y_3$, and $x_4\ y_4$, respectively. Representing the coördinates of the origin by x, y, and z, and the distances of p, p_1, p_2, p_3, and p_4 by d, d_1, d_2, d_3, and d_4, respectively, we have

(a.) $x^2 + y^2 + z^2 = d^2 = v^2 t^2$.
(b.) $(x_1 - x)^2 + (y_1 - y)^2 + z^2 = v^2 t_1^2$.
(c.) $(x_2 - x)^2 + (y_2 - y)^2 + z^2 = v^2 t_2^2$.
(d.) $(x_3 - x)^2 + (y_3 - y)^2 + z^2 = v^2 t_3^2$.
(e.) $(x_4 - x)^2 + (y_4 - y)^2 + z^2 = v^2 t_4^2$.

We know the actual times at which the waves arrived at the places p, p_1, p_2, p_3, p_4, hence we know the values of $t - t_1$, $t - t_2$, $t - t_3$, etc. Denote these differences respectively by m, p, q, and r. Subtracting equation (a) from each of the equations b, c, d, and e, we have

$$x_1^2 + y_1^2 - 2x_1x - 2y_1y = v^2(t_1^2 - t^2) = v^2(m^2 - 2tm).$$
$$x_2^2 + y_2^2 - 2x_2x - 2y_2y = v^2(t_2^2 - t^2) = v^2(p^2 - 2tp).$$
$$x_3^2 + y_3^2 - 2x_3x - 2y_3y = v^2(t_3^2 - t^2) = v^2(q^2 - 2tq).$$
$$x_4^2 + y_4^2 - 2x_4x - 2y_4y = v^2(t_4^2 - t^2) = v^2(r^2 - 2tr).$$

Let $v^2 = u$ and $2v^2 t = w$; then we have

$$2x_1x + 2y_1y + um^2 - wm = x_1^2 + y_1^2.$$
$$2x_2x + 2y_2y + up^2 - wp = x_2^2 + y_2^2.$$
$$2x_3x + 2y_3y + uq^2 - wq = x_3^2 + y_3^2.$$
$$2x_4x + 2y_4y + ur^2 - wr = x_4^2 + y_4^2.$$

We have here four simple equations with four unknown quantities, any one of which can be obtained.

To eliminate many errors due to inaccuracy or want of exactness in the time reports, and errors due to variation in velocity of propagation, I have selected two points as "origin of coördinates," viz., Atlanta, Ga., and Hendersonville, N. C. The ordinates and abscissas were measured along the meridians and parallels respectively. The localities referred to Atlanta as origin together with their coördinates, distance, and time of shock are given in the following list.

Locality.	Abscissa in Miles.	Ordinate in Miles.	Distance in Miles.	Time.
Savannah,	225	— 120	235	9.54
Charleston,	285	— 70	290	9.51½
Raleigh,	330	140	345	9.50
Columbia,	190	15	192	9.48
Beaufort,	215	— 90	230	9.50
Richmond,	400	272	470	9.55
Norfolk,	460	220	505	9.54
Macon,	45	— 65	80	9.55
Weldon,	400	190	440	9.50

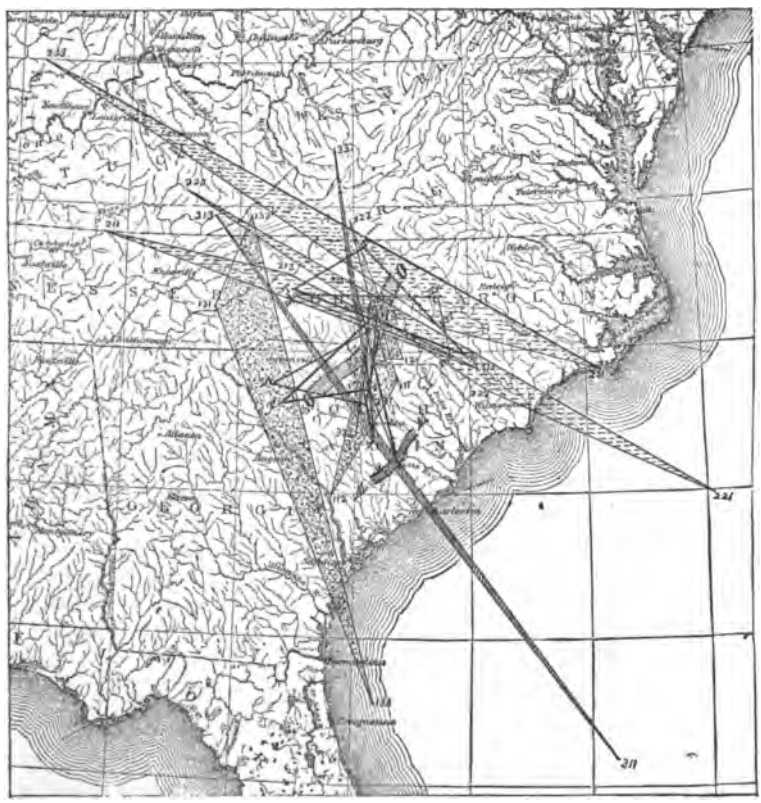
The following were referred to Hendersonville as origin of coörd.

Locality.	Abscissa in Miles.	Ordinate in Miles.	Distance in Miles.	Time.
Savannah,	75	— 230	245	9.54
Weldon,	285	75	300	9.50
Charleston,	140	— 180	230	9.51½
Raleigh,	215	30	215	9.50
Columbia,	80	— 95	125	9.48
Wilmington,	250	— 80	270	9.50
Atlanta,	— 110	— 110	155	10.00
Norfolk,	345	105	365	9.54
Beaufort,	325	— 48	330	9.50
Macon,	65	— 180	190	9.55

The times for Atlanta and Hendersonville were taken at 10.00 and 10.01 respectively—very high, it must be admitted, to represent the time of occurrence of the first shock, but a fair average to include some of the subsequent shocks which followed the first at intervals of only a few moments.

To obtain as fair a result as the data of the problem will admit of, twenty-seven different points were found, the resultant of which gave the final curve O O. The method of obtaining this resultant is as follows: When three points (referred to one common origin of coördinates) were determined, they were connected by straight lines, thus forming a triangle, and the resultant of these points was determined by ascertaining the centre of gravity of the triangle. Now there are three sets of triangles as shown by the shading on the accompanying map; and each set belongs to what I have termed a "combination." So that each "combination" contains three triangles or nine solutions. These nine solutions are divided into sets of three, so that every triangle consists of one set of solutions;

and finally each set consists of three single solutions which correspond to the results indicated by the position of the vertices of the



O O = Line of Origin. M M = Curve of Mean Intensity.

triangle. To illustrate I shall first give below the three "combinations" with their respective "sets" and "groups."

COMBINATION I.

SET I.

Origin of Coördinates, Atlanta.

Group 1.	Group 2.	Group 3.
Savannah.	Savannah.	Savannah.
Charleston.	Charleston.	Charleston.
Raleigh.	Beaufort.	Weldon.
Columbia.	Columbia.	Columbia.

Values of x, y, respectively (243,62), (170,—53), (211,138).

SET 2.

Origin of Coördinates, Hendersonville.

Group 1.	Group 2.	Group 3.
Savannah.	Savannah.	Savannah.
Charleston.	Charleston.	Charleston.
Raleigh.	Wilmington.	Weldon.
	Columbia.	Columbia.

Values of x, y respectively (133,—25), (80,112), (—23,114).

SET 3.

Group 1.	Group 2.	Group 3.
Savannah.	Savannah.	Savannah.
Charleston.	Charleston.	Charleston.
Raleigh.	Columbia.	Atlanta.
Columbia.	Weldon.	

Values of x, y respectively (—50,21), (—20,113), (111,—373).

COMBINATION II.

SET 1.

Origin of Coördinates, Atlanta.

Group 1.	Group 2.	Group 3.
Richmond.	Richmond.	Richmond.
Charleston.	Charleston.	Charleston.
Raleigh.	Beaufort.	Weldon.
Columbia.	Columbia.	Columbia.

Values of x, y respectively (—60,200), (126,164), (318,73).

SET 2.

Group 1.	Group 2.	Group 3.
Norfolk.	Norfolk.	Norfolk.
Charleston.	Charleston.	Charleston.
Raleigh.	Beaufort.	Weldon.
Columbia.	Columbia.	Columbia.

Values of x, y respectively (548,—52), (326,54), (24,247).

SET 3.

Origin of Coördinates, Hendersonville.

Group 1.	Group 2.	Group 3.
Norfolk.	Norfolk.	Norfolk.
Raleigh.	Beaufort.	Weldon.
Columbia.	Columbia.	Columbia.
Charleston.	Charleston.	Charleston.

Values of x, y respectively (323,—40), (165,3), (—237,261).

COMBINATION III.

SET 1.

Origin of Coördinates, Hendersonville.

Group 1.	Group 2.	Group 3.
Norfolk.	Norfolk.	Norfolk.
Raleigh.	Beaufort.	Weldon.
Columbia.	Columbia.	Columbia.
Atlanta.	Atlanta.	Atlanta.

Values of x, y respectively (327,—432), (106,—104), (—50,109).

SET 2.

Origin of Coördinates, Atlanta.

Group 1.	Group 2.	Group 3.
Macon.	Macon.	Macon.
Raleigh.	Beaufort.	Weldon.
Charleston.	Charleston.	Charleston.
Columbia.	Columbia.	Columbia.

Values of x, y respectively (205,75), (197,7), (211,136).

SET 3.

Origin of Coördinates, Hendersonville.

Group 1.	Group 2.	Group 3.
Macon.	Macon.	Macon.
Raleigh.	Beaufort.	Weldon.
Charleston.	Charleston.	Charleston.
Columbia.	Columbia.	Columbia.

Values of x, y, respectively (98,—76), (69,179), (81,51).

Thus, the result obtained by the solution of "Group" 2 under "Set" 2, "Combination" III, would be designated on the map by 322 attached to the vertex, the position of which is determined by the solution of the group, the number 322 signifying Combination III, Set 2, Group 2. In like manner, all other vertices are designated.

Now, the three sets of triangles will give us a second set of resultant triangles (designated by the letter T placed at each vertex), the final resultant of which gives us three points of simultaneous disturbance, which, when connected, gives the curve O O.

The results obtained by this formula are only approximate, for the reasons that: (1) It assumes the velocity of the seismal wave constant. This we know to be true only in cases where the pro-

pagation is through a thoroughly homogeneous medium which is ready to transmit the wave with equal facility in all directions; such, however, is not the case with the earth's crust. (2) It assumes the elevation above sea-level constant for all places, the data of which enter into the formula. Again, the formula is only applicable to localities not too remote from the centre of disturbance; *i.e.*, places that are affected by the "immediate" transmission of the seismal wave through a fairly homogeneous medium. Were the earth thoroughly homogeneous, any inequality of pressure would be transmitted with equal facility in all directions and with equal velocity. Now, if we allow data of localities far remote from the centre of disturbance (say, over 500 miles) to enter into our formula, the results obtained would be unreliable; for, the tremors experienced at such places are the "mediate" effects of the seismal wave propagated through heterogeneous media for a considerable distance, and whose original direction and velocity of propagation has changed with every change of homogeneity, and whose intensity has been variously modified by differences in elasticity and transmitting properties of the rocks traversed.

We should expect, *a priori*, to find the line of original disturbance where the time of shock was earliest. This need not necessarily be the case; for the primary cause of any movement in the earth's crust is due to inequality of pressure brought about undoubtedly by shrinkage. Now, along the Atlantic coastal plain the presence of a line of weakness or fault-line has been established by geologists. Any inequality of pressure along this line would result in a mass movement which would manifest itself either by movement along the fault-line or by the shifting of one rock formation upon another. In either case, movement of this kind would produce seismic effects that would be most severely felt over an area in which the energy of the seismic wave had for some reason or other concentrated; *i.e.*, we should always find an area of *maximum intensity*. Naturally, we should look for the origin in this area, as the disturbance here would be the most violent, and be the first to be noticed. But we can easily imagine how a disturbance (perhaps so slight as to be scarcely perceptible) can originate in a mass of rock at one point, accumulate (a little later) at another point, and be propagated back again to the place of original disturbance. This may well be illustrated in the present case by assuming that some such movement as mentioned, or, indeed,

any movement that might be the resultant of these two variously combined, took place. Now, the amount of movement along a line that determines the general direction in which the motion took place, may be so slight as to be scarcely perceptible, but the energy of the moving mass will be concentrated in certain portions, where the most destructive effects will be produced. This concentrated energy will manifest itself in a region of maximum intensity some time *after* the mass began originally to move, and the seismal waves produced by the concentration of the energy at that point will be transmitted through the strata in all directions, and thus back to the point of origin. Without attempting to discuss the general nature of the movement in the present case, a matter which lies beyond the scope of this paper, it must be admitted that any movement of the crust which may be due to the cause specified or to any combination of these, not only illustrates this point clearly, but satisfactorily accounts for the accumulation of seismic energy in the region where the most destructive effects were produced.

The question might arise, why not regard the resultant of the three points that determine the position of our curve as the "focus" of disturbance? For several reasons: (1) The position of this focus would fall within the area in which the three points were simultaneously affected; *i. e.*, our problem will not admit of such a solution as to place the focus in a region of either earlier or later disturbance than that in which the components of this resultant lie, but simply gives us an additional point on a line of "simultaneous disturbance." (2) Were the origin a "focus," curves of equal intensity would undoubtedly assume the form of iso-seismal ellipses more or less distorted. Any attempt to plot such ellipses on the present earthquake area would prove futile. (3) Inspection of a map of co-seismals at once suggests a linear axis of disturbance, for the co-seismal ellipses are prolonged in a N. E.-S. W. direction. Were the origin a "focus," although the co-seismals would become elliptical at a considerable distance from the origin, owing to heterogeneity of the strata and variation in velocity of propagation, still in regions not too remote from the centre of disturbance, we should expect to find them circular. (4) A focal origin would have a tendency to produce like effects in localities equidistant from the centre, and we might be able to depict some regularity in the nature of the destruction produced. In the pres-

ent case the nature of the destruction is exceedingly complex and in many instances difficult to explain. (5) It will be observed that the tendency of our problem is to distribute the different origins along a series of lines and not about a centre of disturbance.

Curve of Mean Intensity.—As the distance from the centre of disturbance increases, the intensity of the shock decreases. This relation, variable with the nature of the traversed medium, always exists, and we may thus regard distance and intensity as functions of each other. I have thus pursued the following method for ascertaining the curve of mean (practically maximum) intensity. The coördinates of the vertices of the original nine triangles are the results of equations involving the elements of time, velocity, and distance. If now we allow the element of intensity at these vertices to enter as an additional element in our discussion, the resultant position of each triangle will be determined, not by ascertaining its centre of gravity, but by the resultant of three forces applied at, and corresponding to, the intensity of the shock at each vertex. The positions of these resultant triangles on the map, are designated by "In" at each vertex. The resultant of these triangles will give us three points which will serve in the determination of the curve of mean intensity.

We know the intensity of the shocks at these three points; we may regard the intensity at Charleston as 6. Consequently, the curve of mean intensity must assume such a position as is determined by the resultant of the intensities produced at these various points. It will be observed that our intensity curve and line of origin do not coincide, the latter lying some distance northwest of the former.

In conclusion, I desire to express my cordial thanks to Mr. W. J. McGee of the Geological Survey for many valuable suggestions, and to Mr. E. Hayden, for furnishing me with data introduced in the problem.

INFLUENCE OF COPPER ON THE ESTIMATION OF SULPHUR.

BY WM. F. BRUGMAN, '80, CHEMIST, SCRANTON STEEL CO.

WHEN steel, pig-iron, or iron, are dissolved in HCl the sulphur present is given off as H_2S, a trace at most escaping the action of the solvent. Several devices are employed for absorbing and estimating the liberated H_2S, but all presuppose not only the completeness of the above reaction, but the assumption that all the H_2S is eliminated from the decomposing liquid. This might indeed be questioned when metals precipitable by H_2S are present in the material under examination, and reasoning from analogy one might expect that some of the sulphur would become inert through combination in the decomposing flask with such elements if present. Copper, on account of the comparative frequency with which it is encountered, merits our consideration in this respect more than the other members of this group, and some diversity of opinion seems to exist as to the accuracy of the "H_2S method" when this element is present.

G. Craig* shows that in the presence of copper no loss of sulphur is incurred. H. Rocholl† reaches the opposite conclusion, and after a series of experiments states that the loss is proportional to the amount of copper present. M. Troilius,‡ in a paper on the determination of sulphur in steel, says: "As for sulphur being retained in the residue as CuS, when the amount of copper is considerable, this is a matter of rare occurrence, and the presence of 1 per cent. of copper or so would certainly be reason enough for a special searching investigation, not necessary during running work. A steel containing .30 per cent. Cu gave .160 per cent. S, both by the Aqua Regia and bromine ('H_2S method'), and a spiegel with 9 per cent. Mn and ½ per cent. Cu, gave traces of S by both methods." Again, he says,§ "If the steel or iron contain much copper—say more than .250 per cent. or other elements that are precipitated by H_2S in acid solution, the bromine method is apt to give too low results."

* Chem. News, 46, 199 and 272.
† Chem. News, 46, 236.
‡ Inst. Mining Eng., XII., 507.
§ Notes on the Chemistry of Iron.

A large proportion of the steels and pig-irons analyzed at this laboratory contain high copper, and in view of the opinions expressed above I have deemed it imperative to institute a few experiments to satisfy myself as to the accuracy of the method* used under these conditions:

A sample of pig-iron, containing .835 per cent. Cu, gave by the "Aqua Regia Method,"	.228 per cent. S.
Fused with Na_2CO_3 and seppt. gave,	.226 per cent. S.
Sulphur in same iron by "H_2S method,"	.228 per cent. S.
A pig-iron, free from Cu, gave, "H_2S method,"†	.025 per cent. S.
Determination repeated, after adding .035 Cu in the form of chloride, found	.023 per cent. S.
Sample of steel containing .70 per cent Cu gave ("H_2S method"),	.086 per cent. S.
Repeated, adding to drillings .054 CuO, gave " "	.087 per cent. S.
Sample of steel, free from Cu, gave, same method,	.046 per cent. S.
Same, after adding .054 CuO, " "	.048 per cent. S.

In addition to the above I have repeatedly examined the solution remaining in the flask and have never been able to detect a weighable amount of sulphur. These results show that copper exercises no deleterious influence, and can safely be disregarded when present to the amount of 1 per cent.

IN CAMP ON A PRELIMINARY SURVEY.

BY W. H. STUART, C.E.

In the establishing of a line of railroad, the field operations consist of reconnoissance, preliminary, and location surveys, and construction of the road. The reconnoisance is made by the Chief Engineer, with the object of obtaining, by personal inspection, a general knowledge of the country through which it is proposed to run the line.

The preliminary survey is made by an engineer corps, with the view of obtaining accurate detailed and specific information of the route. The location survey is made by a corps of engineers for

* S. of M. Quarterly, V., No. 1.

† 5 grams used.

the purpose of definitely locating the line of the road. The construction of the road is carried out by contract.

In the past summer, I was engaged in a preliminary survey in the Northwest. The line of survey began at a northern part of the Mississippi River, and ran in a general direction north through a narrow valley trailed by ranges of high hills. A small river or stream, from fifty to one hundred feet broad, wound in frequent curves down the valley, and emptied into the Mississippi. The width of the valley varied between about two miles at the mouth, to less than one-half mile at points fifteen or twenty miles above the mouth. The hills on either side were irregular and broken by numerous passes; the bottom lands were partially cultivated, and the timber consisted of elm, oak, pine, and mixed woods.

The party was composed of fifteen members, namely: locating engineer, transitman, leveller, officeman, topographer, assistant topographer, rodman, two chainmen, stakeman, backflagman, two axemen, teamster, and cook.

The tents in the outfit were four in number, the men sleeping in blankets on an armful of hay or straw, if near a friendly field; it is prudent to carry a rubber blanket to spread on the ground beneath the bedding. One tent was devoted exclusively to the use of the cook; the stove was set up, and the food supplies were stored in this tent. The party slept in the three other tents, one of which was known as the office tent, in which was stored the chest filled with note books and general stationery; there was set up in this tent a table for the use of the officeman, in plotting the long roll map of the survey.

The routine of the day's work began with the call to breakfast at 6 A.M.; the party were then driven as near to the last point of the line as the team could reach, and the regular work proceeded until mid-day. One hour for lunch and rest, then work proceeded until near sundown, when the party returned to camp in the wagon or on foot. In the evening, a certain amount of work was done on the day's field notes.

In the progress of the survey, the party was disposed as follows: the teamster was solely occupied with the team, the cook and officeman remained in camp; the function of the officeman was the plotting of the map.

The remaining twelve men were occupied in the field.

The locating engineer was in charge of the entire camp; during

the day he reconnoitred in the field in advance of the line, selecting such courses as seemed, in his judgment, the most desirable to follow; these courses he would indicate to the transitman from time to time.

The transitman ran tangents with the transit, and carried a note book and an Engineer's Field Book.

In running through heavy timber, large trees would frequently interrupt the line of sight; these would be avoided by turning a small angle, in order to save the time lost in felling them.

Frequently the line would strike a spur of the side hills projecting into the valley, and in working around the spur on the slope, only very short sights could be obtained: if the surface of the ground was rough, steeply inclined, and afforded insecure footing, the work would proceed very slowly; and occasionally an order to back up would come from the locating engineer, in order to change the course. The question of curve was a frequent criterion: the limit allowed in curve was six degrees.

The leveller carried a level and note book. His notes were intended to give the relative elevation of every natural feature of interest intersected by the line. At all streams, springs, sloughs, and washouts, very careful inspection was made for signs of high water marks, such as driftwood, eroded banks, etc.; the elevation and location of everything indicating the wash and rise of floods and freshets, was recorded by the leveller, with the date, if possible, of the highest water know to have occurred there. It was frequently possible to obtain these dates with sufficient accuracy, from woodsmen and farmers living in the neighborhood. Bench-marks were established at the rate of at least one in every thousand feet of line: the benches were recorded on rock or on sound trees, from fifteen to forty feet from the line.

The rodman carried in the field a rod, hatchet and note book. His function was to assist the leveller, as indicated above, and record in his note book a system of check-notes of turning points and bench-marks.

These checks were compared with the leveller's at every T. P. and B. M. The rodman required a hatchet to cut benches, blaze trees, and trim off interfering foliage.

The topographer and assistant worked together in the field, and their function was to record such information as would enable the

officeman to plot accurately on the map, all the topography of the country embraced within the limits of the survey.

The topography of the entire valley was required, the limits being the hill ranges on either side. The topographer and assistant carried in the field a hand level, note book, fourteen-foot rod, and a fifty-foot wire-woven linen tape. The elevations of stations were obtained from the leveller as the work progressed, a few at a time, and on all side-hill work contours were put in at even tens of feet in elevation. In the beginning of the survey, two lines of tangents were run in the mouth of the valley, one on either side, and made to intersect each other several miles above; from this point of intersection a single line of tangents was produced up the valley. This was done in order to plot the valley readily in its greater width at the mouth. The topographers plotted all roads and highways, streams, springs, sloughs and washouts, and made note of places bearing signs of high water marks; the base of the hill range on either side of the valley was indicated in the notes, showing spurs and passes; and careful note was made of all side drainages. The nature of the covering of the ground was noted, whether brush grown, timbered, or cultivated: farm buildings were plotted, and the names of the owners recorded. In progressing up the valley, a small village would occasionally be passed through, when the streets and buildings would be recorded with the assistance of a transit and chain; the transit being used to measure the angles of intersection of the streets with the line of tangents, and any other desirable angles; distances would be measured about the village with the chain, tape, and by pacing.

Throughout the course of the survey the transitman would occasionally, each day, measure angles between the tangents and a few prominent points in the valley, as a check on the topography notes; these angles would be used, as in plane table work, by the officeman when plotting on the roll map from the topography notes.

The chainmen carried in the field a chain, flagstaff, and set of pins.

In addition to the establishing of stations at even hundreds of feet, such intermediate points as might be desirable for reference were staked. In rough ground the progress was necessarily very slow, and the winding river of the valley frequently intersected the line.

This river was generally shallow enough to wade, although on one occasion circumstances obliged the head chainman to swim across with one end of the chain.

Occasionally, a suitable tree would be found on the bank near the line, and this would be felled over the water by the axemen to serve as a bridge if the river was narrow enough at that point.

The function of the stakeman was to provide, letter, and drive stakes for the chainmen, and to assist in clearing obstructions from the line with his axe. The stakes he chopped from anything available in the shape of rail fences and brush, and carried them in a canvas pouch.

The backflagman's sole duty was to give backsights with his flagstaff as directed by the transitman.

The axemen cleared obstructions in the advance of the line under the transitman's directions.

It was required of the survey that all government section-lines intersecting the line of tangents should be located in the field and plotted on the map. These lines would not be located at the time they were crossed, but the tangents would be produced for from two to four days; the party would then work exclusively at locating the section lines crossed during that period.

For this purpose the field party would divide into two groups, each group bearing a transit, chain, set of pins, flagstaff, and an axe. The two groups would then proceed to the point of intersection of the tangents with a section line, and one group would locate the section corner on the right, while the other group did the same on the left of the tangents. In case a quarter-section corner was found on either side, it was not necessary to proceed to the full section corner on that side.

As a general thing it required considerable searching to find either quarter- or full section marks; they consisted of wooden posts projecting a small distance above the ground, and were generally found to be badly decayed. These posts were not found in the place they were supposed to be, and frequently were not found at all. The farmers in the neighborhood were occasionally able to indicate the precise location of a corner mark.

While the field members of the party were thus engaged during the day, the officeman worked in camp on the map.

This was made on a long roll of thick, brown paper to a scale of four hundred feet to the inch. The map showed the line of tan-

gents, the section lines, and the topography of the entire valley as recorded in the note books; contours were shown in red, bodies of water in blue, and the base of the hill range on either side of the valley was hatched to show spurs and passes.

In evenings, there was a small amount of office work to be done in camp, principally consisting of plotting profiles of the day's run for the use of the locating engineer; this work was generally done by the leveller, rodman, and either officeman or topographer. These profiles were used by the locating engineer in making estimates of earthwork, bridging, etc. The profile, which was intended to accompany the map of the survey to the general office, was made to show much more detailed information than the profiles just mentioned. For the general office, the finished profile showed the sectional elevation of the ground and the stations, all highway crossings, rivers and streams, sloughs, high water marks and their dates, angles of intersection of the tangents, and the proposed line of grade on which the estimates of the locating engineer were based. The limit of grade allowed was one per cent.; compensation for grade on curve was allowed at the rate of five-hundredths per degree of curve.

On the completion of every twenty miles of tangents, the field-map, profile, and estimates for that section of twenty miles were required by the general office; and once in each month, there was also sent to the general office a list of requisitions for the camp, comprising food supplies, stationery, etc.

In running the tangents, the progress made each day would, of course, vary with the nature of the difficulties to be overcome; an average day's work on alternate hillside, broken ground, and river bottom lands might cover something over two miles.

Camp was generally moved every six or eight miles through the valley; that is to say, the line would be pushed three or four miles in advance of the camp, then a new camping ground would be selected some three or four miles in advance of the line. In open country, these figures would be increased.

In wet weather, the party remained in camp, and employed the time in plotting on the map, calculating quantities of earthwork, and in finishing back work in general.

NOTES ON THE ANALYSIS OF CHROME PAINTS.

BY WALTER LEE BROWN, CHEMIST C. B. & Q. R.R. CO.

HAVING had considerable experience, and not a little trouble, in the analysis of the above paints, I have thought the following notes might be of some aid to the student undertaking such work.

At first glance, and from merely reading over the directions given in the text-books, these analyses seem very simple and easy; they may be the former, but certainly not the latter. Much care and attention to detail are necessary.

The dry chrome paints come on the market in several forms, as lemon chrome or chrome yellow, orange chrome, basic chromate of lead, and chrome green. They can also be procured ground.

1. *Analysis of Mixed Chromate and Sulphate of Lead* (lemon chrome or chrome yellow).—Pulverize the sample, pass through a 100-mesh sieve, and mix. To 1 gram in a small beaker, add HCl and heat. Any insoluble matter (usually barytes as a gross adulteration) is to be filtered out, washed, ignited, and weighed. Further, its weight is to be deducted from that of the total lead weighed as sulphate.

Lead.—1 gram is treated in a covered casserole with 25 c.c. concentrated H_2SO_4, and heated moderately until the residue is perfectly white; cool, dilute with 50 c.c. water, and again cool; add 50 to 75 c.c. of 94 per cent. alcohol, stir, and allow to stand 1 hour. Filter, wash with alcohol as usual, dry, heat, precipitate, and incinerate ash (after treatment with HNO_3 and H_2SO_4) ½ hour, heat again 15 minutes, cool and weigh. The successive weighings should not vary more than $\frac{2}{10}$ milligram.

The process ordinarily performed with HCl and alcohol does not, in our hands, give good results.

The $PbCl_2$ formed will stay neither entirely on the filter nor in the filtrate, and causes trouble all the way through. After repeated trials we had to give it up.

Chromium and Sulphuric Acid (SO_3).—Treat 1 gram with about 25 c.c. concentrated HCl, boil, dilute to 100 c.c., and while hot add excess of NH_4HO, which precipitates the chromium and the greater part of the lead. Boil off the excess of ammonia, filter and wash *very carefully* with hot water.

Precipitate.—PbS reject.

Filtrate.—Boil off every trace of H_2S and precipitate Cr with NH_4HO in the usual manner. Put the moist precipitate and filter paper into a crucible and ignite carefully. Weigh as Cr_2O_3.

Precipitate for Cr.—Dissolve in dilute HCl, neutralize excess of acid with NH_4HO, precipitate Pb with H_2S gas, and filter into a *porcelain dish.*

Filtrate for SO_3.—Acidify with HCl, concentrate, add boiling $BaCl_2$ drop by drop, and determine SO_3 as usual, taking care to wash very thoroughly with hot water.

Occasionally the following determinations are made:

Water—hygroscopic. Heat ½ gram at 220° F. in air-bath, to constant weight.

Volatile Matter.—Heat 1 gram in porcelain crucible to gentle redness; loss, less water, is volatile matter.

Water Extract.—(Acetates, sulphates, bichromates, or nitrates of soluble salts, indicating imperfect washing.) Treat 3 grams with 6 successive portions of 25 c.c. each, of cold distilled water, decanting and filtering each time, and evaporate the filtrate in a platinum dish to dryness on a water-bath.

Calculations.—There are quite a few of these, and the use of factors, as shown by the following example, will save some little time.

Example.—21.62 per cent. $BaSO_4$ obtained; $21.62 \times 1.3 = 28.10$ = per cent. $PbSO_4$. $21.62 \times .888 = 19.19$ = per cent. Pb in the 28.10 per cent. $PbSO_4$ calculated from the 21.62 per cent. $BaSO_4$.

Cr_2O_3 obtained = 16.87 per cent.; $16.87 \times 4.241 = 71.54$ = per cent. $PbCrO_4$.

$16.87 \times 2.716 = 45.81$ = per cent. Pb in the 71.54 per cent. $PbCrO_4$ calculated from the 16.87 per cent. Cr_2O_3.

Total Pb (weighed as $PbSO_4$),	64.45 per cent.
Pb belonging to the $PbSO_4$,	19.19 "
Pb remajning for $PbCrO_4$,	45.26 "
Pb calculated from the Cr_2O_3,	45.81 "
Difference,	.55 "

The 45.26 per cent. Pb calculated to $PbCrO_4$ (45.26×1.561) = 70.65, which is considerably different from the 71.54 obtained from the Cr_2O_3 end. Theoretically, the two chromates should agree; practically they will often differ, according to the complexity of

the pigment. In such cases, and when delicacy of determination is not needed, or time is not available, the fairest way is to average, as one cannot always tell where to place the error. Thus the average of 71.54 and 70.65 = 71.09, this plus 28.10 per cent. $PbSO_4$ gives a total of 99.19.

2. *Analysis of Mixed Chromate, Sulphate and Carbonate of Lead* (lemon chrome and white lead).—Analysis made same as for 1,—excess of lead is to be calculated as white lead, $2PbCO_3 + PbH_2O_2$.

Example.—A sample contained 11.47 per cent. $PbSO_4$ and 48.78 per cent. $PbCrO_4$ (the latter calculated from the Cr_2O_3). Pb in the $PbSO_4$, 7.83 per cent., Pb in the $PbCrO_4$, 31.22; the sum of these, 39.05, deducted from the total lead, 69.95, leaves 30.90; 30.90 × 1.248 = 38.56 = per cent. white lead.

Resumé:	$PbSO_4$, ...	11.47 per cent.
	$PbCrO_4$, ...	48.78 "
	$2PbCO_3 + PbH_2O_2$, ...	38.56 "
		98.81 "

Water, volatile matter, and water extract not determined.

3. *Analysis of Orange Chromate of Lead* (chrome orange).—Process same as for 1. Very little $PbSO_4$ will usually be found. Closer results will generally be obtained from this paint, than from the mixed chromes.

Example.—A sample recently examined gave $PbCrO_4$ from the Cr end, 99 41 per cent.; from the Pb end, 99.34 per cent.; difference, 0.07 per cent. Total analysis as follows:

$PbCrO_4$, ...	99.37 per cent. (average).
$PbSO_4$, ...	0.16 "
Volatile matter, ...	0.50 "
	100.03

4. *Analysis of Mixed Orange Chromate, Sulphate and Carbonate of Lead.*—Same as for 2. Example:

$PbSO_4$, ...	2.73 per cent.
$PbCrO_4$, ...	71.40 "
$2PbCO_3 + PbH_2O_2$, ...	24.56 "
	98.69

5. *Analysis of Red Chromate of Lead* (known by many names, as scarlet, dark or basic chromate of lead, chrome red, Chinese

red, red paste, American vermilion, and vermilion substitute).—Formula, $Cr_2Pb_3O_9$ or $2PbCrO_4 + PbO$.

For the Pb determination take 1 gram in covered casserole, add 25 c.c. concentrated HNO_3, heat to boiling, and *while boiling* add half a dozen drops, one at a time, of alcohol, by means of a pipette; boil a while longer, add water, and all of the chromate, if it is pure, will be found to be in solution. Without this alcohol treatment great difficulty will be experienced in getting the chromate into solution; with it, it becomes very easy. Add 25 c.c. concentrated H_2SO_4, evaporate to white fumes and complete the analysis as described. For Cr and SO_3 determinations boil off alcohol and proceed as previously directed.

Calculations.—Calculate the SO_3 (if there should be any) to $PbSO_4$, and the Cr_2O_3 to $2PbCrO_4$, and subtract their Pb from the total Pb, and figure the remaining Pb to PbO.

Example.—Cr_2O_3 obtained, 13.32 per cent. = 56.49 per cent. $2PbCrO_4$ and 36.17 per cent. Pb. Total Pb = 74.04 per cent.; deduct 36.17 and 1.77 (from the SO_3 found), leaving 36.10 for PbO. $36.10 \times 1.077 = 38.87$ per cent. PbO.

Resumé:	$2PbCrO_4 + PbO$, ...	95.36 per cent.
	$PbSO_4$, ...	2.60 "
	Volatile matter and water, ...	1.24 "
		99.20

6. *Analysis of Chrome Green.*—Composed of Prussian blue and yellow chromate of lead. The latter contains also sulphate of lead.

To 1 gram of the sample add 25 c.c. HCl, heat to boiling several minutes, add water, allow to stand a while, then filter and wash thoroughly with hot water.

Residue.—Prussian blue (plus barytes or other insoluble matter if present). Dry and ignite to Fe_2O_3. Weight multiplied by 2.212 equals per cent. Prussian blue. See Cr det.

Filtrate.—Nearly neutralize with NH_4HO, leaving, however, the solution slightly acid. Pass H_2S gas through till Pb is all precipitated. Filter and wash.

Precipitate.—PbS. Dissolve on filter with hot dilute HNO_3 (1.4) and boil solution. Filter from collected S and bring filtrate of $Pb(NO_3)_2$ to small bulk with several additions of H_2SO_4. Evaporate to fumes of H_2SO_4, cool, add water and alcohol, filter, wash and weigh as $PbSO_4$ as usual.

Filtrate.—For Cr (and Fe), boil off H_2S, add NH_4HO in slight excess, boil this off, and wash the $Cr_2(OH)_6$ (and $Fe_2(OH)_6$), as customary. Weigh precipitate as $Cr_2O_3 + Fe_2O_3$. After the weight is obtained, mix with 1 part KNO_3 and three parts Na_2CO_3, fuse in platinum crucible to clear fusion, cool, boil with water, filter and wash.

Filtrate.—For Cr. Precipitate with NH_4HO in glazed porcelain dish as usual. If the weight of Cr_2O_3 is *very nearly* the same as before, then there has been no Fe extracted from the Prussian blue by the acid treatment. Some varieties are affected by this, others are not. If the weight is less than the original, deduct it from same. the result is Fe_2O_3, which is also to be calculated to Prussian blue and added to the other.

Residue.—Filter, wash, dry, ignite and weigh as Fe_2O_3, if it is wanted as a check.

Sulphuric Acid.—1 gram heated with 25 c.c. HCl, filtered from Prussian blue, and SO_3 in the filtrate determined as directed under 1.

Calculations.—If there is more Pb than is sufficient to combine with all the Cr and SO_3, and a qualitative test shows presence of CO_2, then calculate excess of Pb to $2PbCO_3 + PbH_2O_2$.

Example.—Prussian blue. Per cent. of Fe_2O_3 obtained from the two separations as described, 1.755, multiplied by $2.212 = 3.88$ per cent. Prussian blue; per cent. of Cr_2O_3, $9.20 = 39.01$ per cent. $PbCrO_4$; per cent. of SO_3, $10.56 = 40$ per cent. $PbSO_4$; Pb in $PbCrO_4$ and $PbSO_4$, 52.28 per cent.; total Pb, 65.54, deduct 52.28, remainder, 13.26 per cent. $= 16.54$ per cent. $2PbCO_3 + PbH_2O_2$.

Prussian blue, ...	3.88 per cent.
$PbCrO_4$, ...	39.01 "
$PbSO_4$, ...	40.00 "
$2PbCO_3 + PbH_2O_2$, ...	16.54 "
Total, ...	99.43 "

With all these chrome paints, a qualitative analysis should always precede, in order to make such modifications of the after treatment as may be necessary.

To determine the mixing fluid in any ground chromate, tare a small beaker and weigh into it from 10 to 15 grams of the paint. Stir the paint three times with naphtha, using about 25 c.c. each time, and withdrawing the mixing fluid solution by means of a

small suction pipette, such as is used for filling stylographic pens, etc. Finally, treat once with ether, withdraw same, dry beaker and contents, and weigh; loss equals mixing fluid.

Table of Factors.

(Ba = 137, C = 12, Cr = 52.2, Fe = 56, H = 1, K = 39, N = 14, O = 16, Pb = 207, S = 32.)

Found. a	*Sought.* b	*Multiply by factor.* $\frac{b}{a}=f$
$BaSO_4$ (233)	$PbSO_4$ (303)	1.300
$BaSO_4$ (233)	Pb (207)	0.888
Cr_2O_3 (152.4)	$2(PbCrO_4)$ (646.4)	4.241
Cr_2O_3 (152.4)	2Pb (414)	2.716
Fe_2O_3 (160)	$K_2Fe_2(FeCN)_2$ (354)	2.212
Pb (207)	PbO (223)	1.077
Pb (207)	$PbCrO_4$ (323.2)	1.561
3Pb (621)	$2PbCO_3 + PbH_2O_2$ (775)	1.248
$PbCrO_4$ (323.2)	Pb (207)	0.640
$PbSO_4$ (303)	Pb (207)	0.683
SO_3 (80)	$PbSO_4$ (303)	3.7875

References.—Fresenius' *Quantitative Analysis;* Rammelsberg's *Guide to a Course of Quantitative Chemical Analysis;* Wöhler's *Handbook of Mineral Analysis;* Normandy's *Commercial Handbook of Chemical Analysis;* "Simple Exercises in Technical Analysis" (entirely on paints), in *English Mechanic and World of Science*, London, from August 8th, 1884, to date, at intervals; *Painting and Painters' Materials*, by C. L. Condit.

Credit is herewith given to my assistants, George H. Ellis and E. Speidel, and to E. M. Bruce, for the careful working out of the processes described in this article.

BOOK REVIEWS.

TRACK, A COMPLETE MANUAL OF MAINTENANCE OF WAY. By W. B. Parsons, Jr., C.E.

This book of 111 pages deserves more than a passing mention. It has been prepared by one of the graduates of 1882 in the course of civil engineering from the School of Mines, first for publication in *Engineering News*, and it now appears in book-form. It follows very closely the lines marked out in the course of lectures delivered in the School of Mines on Permanent Way, in the civil engineering course, and students for that degree may find the book a useful adjunct in that special line of study.

In many respects, as giving the results of the author's own experience, the work has valuable features. Perhaps the most striking one is the series of data as to what amount of work it is reasonable to expect from employés of the road, whether on track-work or in making tools, and as to the number of men who should constitute a gang, in relation to the length of the sections. The list and description of the kit of tools is very full and complete, and, being brought down to 1886, is superior to what may be found in earlier books on the subject.

It is quite novel, also, to find bills of material for tool-houses and watchmen's shanties, with drawings; and the fence details, mail crane and bridge "tickler" are not found elsewhere. Similarly, also, the observations on track-work, being results of experience, will be found readable and valuable, particularly in the matter of snow.

The book is very copiously illustrated, the last cut being Fig. 122. These illustrations are, many of them, reproductions of trunk-line standards, or have appeared in the railroad journals at one time or another, as illustrating articles of special manufacture. It is convenient, however, to have so much of information of this type gathered together from the catalogues and other original sources whence they have been derived. It is possible, therefore, from these standpoints to give the book the commendation which it deserves.

On the other hand, many readers will find their general impression of the book to be unsatisfactory. It is, of course, difficult to know what audience the author had before his mind and was trying to reach. For educated men who have had a special training, and who keep up a familiarity with periodical literature, the discussions of rails, joints, switches and metal ties is far from complete, and much of the elementary detail, which is given, would not be called for. There is foreign practice in several directions, to which profitable reference might be made in a treatise which aimed to be exhaustive, and much turnout and siding detail is omitted. Similarly, also, many of the directions and suggestions would be the commonplaces of a man who was using his brains in his profession. In the second place, for the trackmen, themselves without technical training, nor having access to railroad journals, much of the matter would be telling them, either what they already know or care but little about knowing, and all which they would find of value would be the directions as to methods of doing work to secure the best results. The entire catalogue-information would be wasted on them, as they have no selecting or purchasing functions. As a compilation of standards, however, of leading roads, it may be stimulating reading for the track-department of lines of the second and third class.

It would seem that the class who would get most good from the book would consist of any young men in the track department of railroads, who had received a general engineering training and who were ambitious to find out the facts of their specialty in the least time, with a view to securing rapid promotion. The School of Mines is, perhaps, the only technical school making a specialty of this particular branch for its civil engineers, and, for those who do not have these opportunities, the book will be of special value. Those who are so favored will find it an admirable review of their knowledge. F. R. H.

A CATALOGUE OF MINERALS. Alphabetically arranged, with their chemical composition and synonyms. By Albert H. Chester, Professor of Mineralogy at Hamilton College. JOHN WILEY & SONS. 1886. 52 pp. Cloth. Octavo.

This catalogue comprises about two thousand English names of mineral species and varieties, and is intended to embrace all English names now in use. It includes the recent additions to the nomenclature, omits "dead and useless" names, and distinguishes between well-authenticated and doubtful species and varieties. *

THEORY AND PRACTICE OF SURVEYING. By J. B. Johnson, C.E., Professor of Civil Engineering, in Washington University, St. Louis. JOHN WILEY & SONS.

In this work, of nearly 700 pages, Professor Johnson has covered the entire field of surveying, from land surveying, as it is technically understood, to the more elaborate and difficult science of geodesy.

Modern writers tend, as a rule, to more systematic treatment of engineering subjects than their predecessors, and works on surveying are no exceptions. One of the best features of Professor Johnson's book, is its logical treatment, the clear separation of each branch from the other, and their discussion in the order that best unfolds the subject to the student.

The inference from the preface is, that the wants of students were kept specially in the author's mind in writing, and, as a result, the book is well adapted as a text-book for their instruction.

Many of the chapters are followed by a set of problems, or a scheme of field work, best adapted to bring into actual practice the principles and methods previously given.

It must not be inferred that the work is one of service in technical schools merely. It cannot but be of value as a book of reference in any surveyor's or engineer's library.

Nevertheless, it is impossible, in modern times, to include within the covers of any reasonable volume all that is known on the subject of surveying, and supply the specialist with all the data of his particular branch, and so, he who expects an exhaustive treatise in every particular, will be disappointed.

The author may, possibly, be criticised in parts for attempting to cover too much ground with his survey, and leaving in places merely the bare lines of his triangulation, with few details of topography. Thus, for example, it is a question, if the chapter of 12 pages on railroad surveying might not better be omitted, as it gives merely a skeleton which the reader would find it absolutely necessary to clothe with leaves from other books; a fact that is acknowledged in a foot-note.

One point to be noted is, the coöperation of specialists in the writing of the chapters on mine surveying and city surveying,—a wise plan, which has recently been adopted by the authors of books on surveying.

The work is divided into two sections.

Book I treats, in 167 pages, of the "Adjustment, Use, and Care of Instruments," taking them in order, from chain to transit, solar compass, barometer, planimeter, etc,, and clearly showing how to intelligently use and preserve them.

Book II covers 510 pages, and gives methods of surveying under the following headings: "Land," "Topographical," "Railroad," "Hydrographical," "Mining," "City," and "Geodetic." Then follow: "Surveys for the Measurement of Volumes" and the "Projection of Maps, Map Lettering, and Topographical Signs." In the chapter on "Topographical Surveying," special attention is paid to the use of the Stadia rod, and, in fact, that method only is employed, as the use of compass and plane table was previously described. Under "Hydrographic Surveying," is included a topic not usually seen in books on survey, viz.: The gauging of flow of water in channels, weirs and streams.

The use of the steel tape for accurate measurement is given in detail, and the assertion made, that it, or the use of wires of steel and brass, will probably supersede the use of base line apparatus, even for the measurement of primary base lines.

In the end of the volume, are several specimens of topography, an Isogonic chart of the United States for 1885, and a number of useful appendices. The tables that always accompany works of this character are at the end of the book, and include trigonometric formulæ, tables for conversion of feet, metres, and chains, logarithmic tables, logarithmic traverse tables, tables for stadia readings, for natural sines and cosines, for tangents and cotangents, for flow, for size of brick conduits related to discharge, for the use of the prismoidal formula, and finally, a table for service in polyconic projection. **

PRINCIPLES AND METHODS OF SOIL ANALYSIS. By Edgar Richards. Department of Agriculture. Bulletin, No. 10. Washington, 1886.

Mr. Richards, Assistant Chemist to the Department, has here given in concise and valuable form a *resumé* of the methods of analysis at present employed, together with a great deal of general information in regard to the properties of various kinds of soils, their formation, the composition of the inorganic constituents of ordinary crops, the cereals, root-crops, etc. In the introductory words of the author, "An attempt has been made to collect such information on the subject of soils, now scattered through so many different books and periodicals, as will be of general interest."

To the chemist, who may be asked to decide upon the probable fertility or the best mode of cultivation of a soil, this Bulletin will be of value, "while the reader who is not a chemist will discover a valuable fund of information about soils and their treatment." Of course, it is outside the province of the Government to furnish an exhaustive treatise on the subject, but wherever possible references are given to the works consulted, which the reader may turn to for fuller information. †

ABSTRACT.

The Crystalline Structure of Iron Meteorites.

Iron meteorites are now generally classified into two chief groups: the octahedral and the cubic, the distinction being based upon the fact that the Widmanstättian figures and Neumann lines, brought out by etching polished sections, are supposed to mark, respectively, an octahedral and a cubic structure. This classification, however, cannot be a natural one, as equally competent observers differ as to the character of the figures, and the figures themselves often differ, even in different parts of the same section.

Mr. O. W. Huntington has still further studied the crystalline structure of iron meteorites, and presents the results in a very interesting paper in the October number of the *American Journal of Science*, from which we have taken the following statements:

The investigations were made upon the specimens of the Harvard College collection. Many of the specimens were like rough octahedrons, their irregular faces being parallel to planes of fracture, and in definite relation to the Widmanstättian figures. The plan adopted was to polish and etch surfaces either parallel to the cleavage planes, or in a known position towards them, and on these study the crystalline plates whose cross sections form the Widmanstättian figures.

The result of the experiments was to indicate that there is no sharp line of demarcation between octahedral and cubic meteorites.

In a specimen of the De Kalb Co. meteorite which showed hollow octahedral faces, built up of a series of plates about half an inch wide and one-sixteenth of an inch thick, when cut and etched, parallel to an octahedral face, the Widmanstättian figures all made equilateral triangles, their sides being parallel to the octahedral edges.

The Coahuila iron showed, in one specimen, markings parallel to both cube and octahedron, but in another fragment in *actual contact* with the first, all the lines could be referred to the cube.

The Butler iron was easily cleavable into octahedrons, and the majority of the plates, even the most microscopic, followed the direction of the octahedral faces, but in addition, there were certain plates which, in one face, bisected the facial angle of the octahedron, and followed to the next face were parallel to an octahedral edge, showing them to be dodecahedral.

The Hauptmannsdorf iron broke with a cubic fracture, and all the lines could be referred to the cube.

The La Caille meteorite, cut parallel to an assumed cube face, gave not only the rectangular lines which would result from octahedral plates, but also diagonal lines which, when traced to an adjacent face, followed the direction of a dodecahedral plane, and were exactly parallel to a large natural face. This natural face made with an adjacent octahedral face an angle of 145°, corresponding to the dodecahedron.

The author's conclusion is as follows:

"It is evident that there is a regular unbroken gradation between the coarsest Widmanstättian figures and the finest Neumann lines; so that we can arrange a series consisting of the irons of Nelson Co., Wichita Co., Glorieta, Red River, Robertson Co., Dickson Co., Oldham Co., Jewell Hill, Obernkirchen, Tazewell, Butler, Walker Co., Coahuila, and Hauptmannsdorf, in which there is no gap at which a definite line of demarcation can be drawn.

"Moreover, there is no difference in crystalline form even so slight as that between the three fundamental forms of the isometric system, for, as has been shown, the coarsest Widmanstättian figures, as well as the finest Neumann lines, are intersections of planes of crystalline structure which may be parallel to the faces of the octahedron, the dodecahedron, or the cube."

The Germans strongly insist on the division into Kamacite, Tænite, and Plessite, describing these as if essentially different substances. The plates whose sections are the Widmanstättian figures are called Kamacite; they are separated from the mass by a thin layer of iron richer in nickel, called Tænite. This material is not easily acted upon by acid, and appears on the etched surface as a bright silvery line along the edge of the Kamacite plates. The groundmass is called Plessite. It is probable that these are only different conditions of nickeliferous iron produced by slow crystallization. As the metal cooled, the purer iron would crystallize first, and subsequently the less pure. Alternations of such stages would result in the production of a succession of plates of comparatively pure metal, interlaminated with a richer nickel alloy.

The determining cause for the octahedral or cubic structure is not known. The presence of foreign matter in a crystallizing menstruum, produces a marked influence on the result. Salt, ordinarily cubical, will, in presence of urea, crystallize in octahedrons. In the Hauptmannsdorf iron, there is a prevailing cubic structure, but where the iron has excluded foreign material, as shown by inclusions of graphite, troilite, schreibersite and the like, the octahedral form prevails.

It is further to be noticed, that on the section of kamacite plates in characteristic octahedral irons, fine lines, evidently identical with the Neumann lines, appear. It is probable, therefore, that the coarser octahedral structure which gives rise to the Widmanstättian lines, is connected with the exclusion of incompatible material during crystallizatior, and that the more uniform structure of the cubic meteorites marked by the Neumann lines, results from the circumstance that the iron or alloy is capable of crystallizing in mass.

Octahedral irons are then not more definite in composition than cubic irons, but in the first case there is an elimination, during crystallization, of the various materials which form the Widmanstättian plates, while in the second case no such elimination takes place. The element of time may be the chief condition in determining the result, for we should naturally expect that during a very slow crystallization, foreign material would be more completely eliminated than during a process which was comparatively rapid.

The points the paper tries to establish are:

"Many of the masses of meteoric iron in our collections are cleavage crystals, broken off, probably, by the impact of the mass against the atmosphere.

"These masses show cleavages parallel to the planes of the octahedron, cube and dodecahedron.

"The Widmanstättian figures and Neumann lines are sections of planes of crystalline growth parallel to the same three fundamental forms of the isometric system.

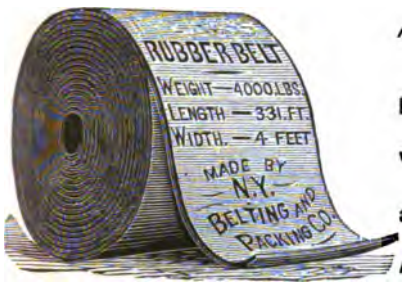
"On different sections of meteorites Widmanstättian figures and Neumann lines can be exhibited in every gradation, from the broadest bands to the finest markings, with no break where a natural line of division can be drawn.

"The features of the Widmanstättian figures are due to the elimination of incompatible material during the process of 'crystallization.'"

RUBBER BELTING, PACKING, HOSE,

RUBBER TUBING, RUBBER MATS,

MATTING, and STAIR TREADS.



All kinds of Rubber Goods for Mechanical Purposes.

DIAPHRAGHMS, GASKETS and RINGS, ROLLS, STOPPLES, VALVES and TUBING—BLACK or WHITE, for GAS, WATER, and INSULATING RUBBER BAGS.

Largest Manufacturers in the U. S.

New York Belting and Packing Co.,

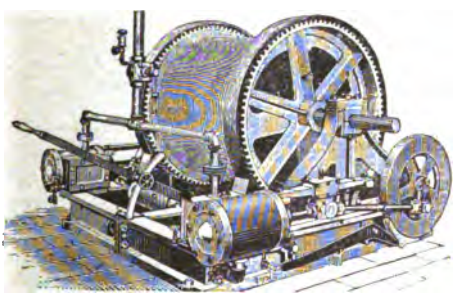
15 PARK ROW (Opposite Post Office), **NEW YORK.**

JOHN H. CHEEVER, TREASURER.

Improved Hoisting Engines

WITH

Wire-Rope Drums and Safety Brakes.



Specially adapted to Mining Interests.

ALSO COMBINED

Engines and Boilers, and Horizontal Stationary Engines.

LIDGERWOOD MFG. CO., 96 Liberty St., N. Y.

NEW CATALOGUES NOW READY.

WOODBRIDGE SCHOOL

(Late School of Mines Preparatory School)

No. 32 EAST FORTY-FIFTH STREET,

NEW YORK.

Distinct Scientific and Classical Courses, introductory to all colleges; also Junior Department. The Scientific Course is carefully planned to be preparatory to the Columbia School of Mines.

INSTRUCTORS

PRINCIPAL:

J. WOODBRIDGE DAVIS, C. E., Ph.D.,
Mathematics, English.

ASSISTANTS:

PHILIPP J. J. VALENTINI, Ph.D.,
German Language.

APPLETON P. LYON, A.M.,
English and Classical Languages.

JOHN K. GORE, A.M.,
Mathematics, History.

FERDINAND G. WEICHMANN, Ph.D.,
Chemistry, Physics.

A. L. SEVESTRE,
French Language.

H. L. FAIRCHILD, B.S.,
Comparative Physiology, Geology.

HOBART B. JACOBS,
Drawing.

ARTHUR H. WOODBURY, A.B.,
Latin, English Grammar.

Registered at the New York Post Office as Second Class Matter.

VOL. VIII. No. 2.

THE

SCHOOL OF MINES QUARTERLY.

JANUARY, 1887.

CONTENTS:

On New Features in Teledynamic Transmitters. By Prof. Reuleaux, 93
On the Action of Hydrofluoric Acid on Silica and Silicates. By J. B. Mackintosh..... 115
Treatment of Gold in the Arrastra. By T. Egleston, Ph.D. 125
The Great Telescopes of the World. By J. K. Rees..... 135
Analyses of Franklinite and some Associated Minerals. By George C. Stone..... 148
Our Grandest Mountain and Deepest Forest. By Bailey Willis..... 152
A Letter from President Barnard..... 164
Additions to the Columbia College Library in the Department of Natural Science, Useful and Fine Arts, Oct. to Dec. 1886..... 167
Index of Current Literature Relating to American Geology. By F. J. H. Merrill..... 172
Professional Notes..... 174
Abstracts..... 180

COLUMBIA COLLEGE.

NEW YORK CITY.

1887.

SCHOOL OF MINES QUARTERLY.

VOL. VIII., 1886-87.

EDITORS.—J. L. GREENLEAF, *Managing Editor;* A. J. MOSES, *Business Manager;* J. K. REES, J. B. MACKINTOSH, E. A. CONGDON, H. PARSONS.

ASSOCIATE EDITORS.—F. A. P. BARNARD, J. S. NEWBERRY, T. EGLESTON, W. P. TROWBRIDGE, H. S. MUNROE, F. R. HUTTON, ELWYN WALLER, P. DE P. RICKETTS, M. W. ILES, R. D. IRVING, H. B. CORNWALL, P. T. AUSTEN, C. M. ROLKER, J. A. CHURCH, W. B. POTTER, S. A. REED, W. B. DEVEREUX, J. M. ADAMS, H. M. WILSON, J. C. F. RANDOLPH.

Subscription price two dollars per annum, or fifty cents per number. Address

SCHOOL OF MINES QUARTERLY, New York City.

FIELD, ROBERT P.,

CONSULTING,

Mining and Civil Engineer.

Coal Mining and Coking a Specialty.

148 S. Fourth Street, Philada., Pa.

Box 1228.

OLCOTT, EBEN E., E.M.,

MINING ENGINEER

AND

METALLURGIST,

10 Cedar Street, New York City

Cable address, "Kramolena."

Examines and reports on mines or metallurgical establishments.

Has had considerable experience in Gold and Silver Mines in South America and Mexico.

Eastern representative of the M. P. Boss Continuous Milling System.

LEDOUX & COMPANY,

Consulting Engineers and Metallurgists,

10 Cedar Street, New York.

Complete Sample Works and Laboratories. Assaying, Sampling, Concentrating and Milling small or large lots of ANY ORE. NEW PROCESSES and NEW MACHINES tried, and their PRACTICAL VALUE determined.

Mineral and Commercial Analyses of all kinds.

☞ Special terms and inducements offered to professional men, including School of Mines Alumni.

PISTOR, WILLIAM,

ARCHITECT,

No. 35 Broad St.,

NEW YORK.

LEGGETT, THOS. H.,

Mining Engineer,

San Juancito, Tegucigalpa,

HONDURAS, C. A.

Cable Address—"Leggett, Honduras."

JOHN C. F. RANDOLPH,

Consulting Mining Engineer,

35 BROADWAY, NEW YORK.

MAYNARD, GEO. W.,

Mining and Metallurgical

ENGINEER.

Designs for Mining, Dressing, and Metallurgical Plants.

OFFICE, 35 BROADWAY, NEW YORK.

STEARNS, T. B. & CO.,

Consulting, Mining and Mechanical

ENGINEERS,

CONTRACTORS AND AGENTS,

Nos. 3 and 4 Duff Block,

DENVER, COL.

THE

SCHOOL OF MINES QUARTERLY.

VOL. VIII. JANUARY, 1887. No. 2.

ON NEW FEATURES IN TELEDYNAMIC TRANSMITTERS.

BY PROFESSOR REULEAUX.*

THE problem of conducting motive power over long distances has recurred in engineering practice with ever growing frequency during the past few decades. Natural water-power is carried by wire rope to mills located on more favorable sites than those in immediate vicinity of the falls; artificial falls are produced by pumps, and transmitted through piping to distant tunnel workings, or to hydraulic engines which utilize the power; compressed air finds similar application; and vacuum or rarefied air has been used for the same purpose—recently even on quite an extended scale in the city of Paris, according to reports of the technical press. Steam, too, has sought to assert itself in the field of teledynamic transmission,† particularly in America, where we find it distributed from central boiler stations through ramifying conduits, to furnish heat and power. Not long ago report rumored of a similar project pending for the city of Berlin, but this now seems to have been postponed, if not, indeed, definitely consigned to the limbo of abortive schemes. Our own times, of late, have been occupied

* *Ueber Neuerungen in Ferntriebwerken:* an address delivered before the Railway Science Association in Berlin, Germany. Translated for the SCHOOL OF MINES QUARTERLY by Wheaton Kunhardt, E.M.

† Or *Ferntrieb*, as I proposed to call the system a number of years ago.

with altogether special prospects for utilizing the electric current in transmitting power. The public at large is alive to the question, and eagerly lends ear to accounts of such projects. Though the stir about wiring to New York even a half-way respectable fraction of the six million horse-power of Niagara has somewhat subsided, yet an ever favorite theme for our popular magazine mechanics is the wasted energy of Alpine torrents—how it might be carried from inhospitable mountain fastnesses into the cultivated plain below, to the lasting benefit of industry. This subject of wild, unchecked elemental forces I would revert to further on. But notwithstanding many such exaggerations, the gist of the idea—the recognized importance of teledynamics—subsists with undiminished vitality even in the sober technical mind. In evidence we may point to some of the more modern railway dépôts, whose spreading dimensions endue with correspondingly growing interest the problem of transmitting power to distant points.

While I propose to discuss several noteworthy innovations in the plants for power transmission, I may be permitted at the outset to restate certain mechanical principles which may, perhaps, be put into more serviceable shape for our purpose than has heretofore been done. As a starting-point I select belt transmission. In the case of a belt passing over a pulley which it is to drive with an effective tangential force, P, the slack side must possess a certain tension, t, to prevent any slip upon the pulley, so that the actual working tension T of the driving side will exceed P by a certain amount, t, and we shall always have $T > P$. The value of t depends on the arc of contact, and also on nature of the pulley face and that of the contact surface of the belt. Assume $T = \tau P$ in which τ is a coefficient greater than 1, whose value we regard as known. It may be called the modulus of tension, as it indicates the stress to which the tauter side of the belt must be subjected in order that it may transmit the force P to the driven pulley, or take it up, at the other end, from the driver. The cross-section of the belt is readily found from the tension $T = \tau P$, for, denoting its breadth in mm. by β, its thickness by θ, and the permissible working stress per square millimeter of cross-section by $\mathfrak{S}$, we have $T = \tau P = \beta\theta\mathfrak{S}$, whence $P = \beta\theta\mathfrak{S} \div \tau$. If v denote the velocity of the belt in meters per second, and N the horse-power transmitted,* then $N = Pv \div 75 = \beta\theta\mathfrak{S}v \div 75\,\tau$. From an ex-

* 75 Kilogrammeters per second = 1 horse-power.—TRANS.

pression such as this, the width of the belt is commonly determined by introducing suitable values for τ, θ, and $\mathfrak{S}$, according to the kind of material—leather, rubber, canvas, etc.—that is employed. In this way a number of formulæ for widths of belts have been developed, which, though exhibiting no inconsiderable differences, are all met with in various forms by the practicing engineer.

It is just here that I would propose a new departure. The product $\beta\theta$ is the cross-section of the belt in square millimeters. If the same section, expressed in square centimeters, be denoted by q, then $q = \beta\theta \div 100$, and we have $N = 100\, qv\, \mathfrak{S} \div 75\, \tau$, or

$$(1) \qquad N = \frac{4}{3}\frac{\mathfrak{S}}{\tau} qv.$$

The simple form of this expression for N is its recommendation but it is still further improved for practical use by dividing both members by qv, for the quotient $N \div qv$ denotes the horse-power which the belt transmits for each square centimeter of cross-section and each meter of velocity per second. Denoting this value by N_0, we have

$$(2) \qquad N_0 = \frac{N}{qv} = \frac{4}{3}\frac{\mathfrak{S}}{\tau}.$$

This duty of the belt per square centimeter of cross-section and meter velocity is referred to $\mathfrak{S}$ and τ alone—$\mathfrak{S}$ depending upon the material of the belt, and τ upon the nature of the contact faces in the belt and pulley. The right hand member of the equation is, therefore, a function of physical properties, revealing in this respect an analogy with specific gravity, which is equally a function of properties of matter. I propose, therefore, to designate the above defined capacity, or effectiveness, N_0, as the *specific duty** of the belt.

When the specific duty of a belt is known its dimensions are very easily found. In leather belts the specific duty in average cases is $N_0 = \frac{1}{5}$, so that if it be required to determine the proper size of such a belt for transmitting, say, 60 horse-power, we have

* *Spezifische Leistung.*

only to assume a speed—*e. g.*, 15 meters per second—and then obtain directly from formula (2),

$$q = N \div vN_0 = 60 \div 15 \cdot \tfrac{1}{5} = 60 \div 3 = 20 \text{ sq. cm.}$$

A double belt, 10 mm. thick and 200 mm. wide, would meet the case.* With $v = 20$, the cross-section would be $q = 60 \div 20 \cdot \frac{1}{5}$ $= 15$ sq. cm., and so on. The specific duties of belts differ according to the material of which they are made. I have found by careful experiment as average values for

Cotton belts, $N_0 = \frac{1}{7}$,
Rubber belts, $N_0 = \frac{1}{8}$,
Leather belts, $N_0 = \frac{1}{6}$.†

It is obvious that the better material gives a higher specific duty. Belt manufacturers might, therefore, with eminent propriety confine themselves to stating the specific duties which they are prepared to offer, rather than burden their price catalogues with the familiar long list of testimonials from which the true capacity of their belts can only be judged with difficulty. On the other hand, the admission of the specific duty into contracts would afford a positive expression for the work which could be required of the belt.‡ The calculation just made for belts holds good without the least change for all other wrapping connectors, as hemp and wire rope, which transmit power with pulleys. Just at present hemp rope is much used—is, I might say, fairly in the height of fashion. For

* For English units, let q' = cross-section of belt in square inches, $\mathfrak{S}'$ = safe working stress per square inch, v' = velocity of the belt in hundreds of feet per minute, and N'_0 = specific duty; then $N = q'\mathfrak{S}'v' \div 330\,r$ and $N'_0 = \frac{1}{330}\frac{\mathfrak{S}'}{r}$. Assuming $\mathfrak{S}'$ at the unit-stress of 540 pounds, and $r = 2.5$ (see table), we find $N'_0 = 0.64$, which is the horse-power transmitted for each square inch of belt cross-section and each 100 feet velocity per minute. In the problem of transmitting 60 horse-power, as above, we find $v' = 29.52$, and $q' = \frac{N}{v'N'_0} = \frac{60}{29.52 \times 0.64} = 3.2$ square inches, or, practically, 20 sq. cm.—TRANS.

† The specific duties for English units, as in the foregoing note, are respectively 0.45, 0.53, and 0.54.—TRANS.

‡ I may mention, in passing, that the Berlin representatives of the well-known Manchester firm of Simon, makers of excellent cotton canvas belts, have by my advice for a year past rated and guaranteed their belts on the basis of a specific duty of $\frac{1}{7}$. This figure, which I had determined by a long series of experiments, has been abundantly verified in their practice.

the technical arts have their fashions just as men's and women's dress have theirs, with this difference only, that technical fashions are apt to be far more expensive than head-gear and crinolines. But the real value of any power transmitter can be ascertained, to a certain extent at least, from its specific duty. This for hemp rope is $\frac{1}{8}$ to $\frac{1}{16}$, and in the majority of normal cases may be taken at

$$N_0 = \frac{1}{12}*$$

Figuring from data in the current price list of the Berlin-Anhalt Machine Building Company, the specific duty which they offer in their hemp rope proves to be $\frac{1}{12.5}$.† In the Gera Jute Spinning Works the driving engine has a fly-wheel with 30 grooves, for ropes 60 mm. thick, the number used at any one time being proportioned to the demands for power. With a velocity of 15 meters per second, each rope transmits 25 horse-power; hence we find for the specific duty $N_0 = 25 \div 15 \cdot 28.3 =$ approx. $\frac{1}{17}$. This method of using side by side a larger or smaller number of bands, or ropes, according to the power required, has led to remarkable applications of hemp rope, as illustrated in a 60-rope plant transmitting 4000 horse-power.‡ My own opinion is, however, that our present mode of applying hemp rope, particularly with such many grooved pulleys, is not economical. My argument in support of this view has appeared elsewhere, and need not be repeated here.§

Wire rope has a very favorable specific duty: first, for the reason that when the groove in the pulley rim is filled with leather, the modulus of tension falls as low as 2—instead of being 2.5 as for belts—and next, because the unit tensile stress $\mathfrak{S}$ may be high. For iron wire we may run up to 6–7½ kg. per sq. mm., and for steel wire as high as 12–15 kg. Introducing the value $\tau = 2$ into formula (2) we obtain for wire rope

$$N_0 = \frac{2}{3}\mathfrak{S},$$

---

* Or in English units $N'_0 = 0.28$—TRANS.

† In English units $N'_0 = 0.26$—TRANS.

‡ Engineer, January, 1884, p. 38. The fly-wheel which serves as driving pulley has a diameter of 60 feet, and a 15-foot face with 60 grooves; its weight is 140 tons.

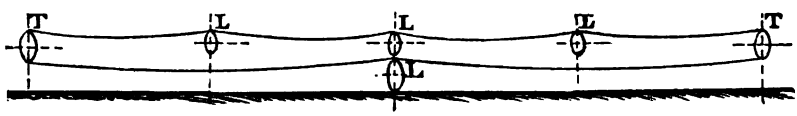
§ Author's Konstrukteur, 4th edition, p. 787.

and from this for iron rope, $N_0 = 4$ to 5; and for steel rope, $N_0 = 8$ to 10.*

These numerical values show at once why wire rope plays so prominent a role in long distance transmission, casting belting and hemp rope completely into the shade. Steel rope, it appears, can render specifically 100 to 120 times as much work as hemp rope.

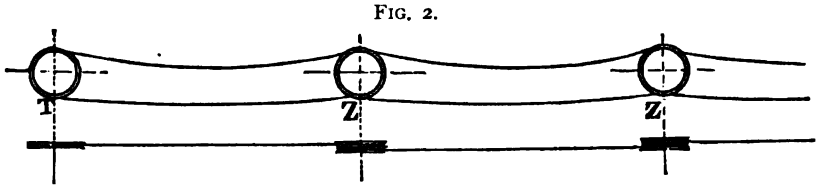
Ever since 1854, when Ferdinand and Adolph Hirn invented, if we may so express it, wire rope transmission at Logelbach near Kolmar, this system has been extensively used, and its adoption is still steadily gaining ground, notably in Southern Germany, Switzerland and Austria, and also in Sweden and Russia and locally in the United States. The erection of the plant has by no means always been a simple matter; sometimes constructive details have required the most careful consideration. This is especially true of the points of support, or stations, along the line of

FIG. 1.



the rope. When the distance between the driving and following pulleys is considerable, the slack side of the rope must be supported twice as often as the taut or driving side, as illustrated in Fig. 1, and the station pillars, or standards, must obviously be of

FIG. 2.



sufficient height to allow for all necessary headway beneath the rope.

Another arrangement, with intermediate driving-wheels (Fig. 2), was introduced by the eminent engineer Ziegler, and has been embodied by him in a succession of excellent lines. The pulleys have

* In English units, for iron wire $N'_0 = 12.8$ to 16; for steel wire $N'_0 = 25.6$ to 2.—TRANS.

two separate grooves, each single wheel practically taking the place of two; this divides up the long line into several consecutive shorter ones, which Ziegler proportions in equal lengths, so as to be able at any time to replace a worn rope by one which is already spliced and held in reserve. The standard in this case also must be as high as the lower chord of the rope demands, but it is evident that it may be shorter than a support which carries two wheels, set as in Fig. 1.

To indicate clearly the significance of long distance power transmission by wire rope, it may not be inappropriate to dwell for a few moments on a description of some of the larger wire rope lines.*

The line of the yarn mill on the "Hohe Mark," at Oberursel, near Frankfort-on-the-Main, transmits 104 horse-power over a distance of 966 meters; it is divided into eight equal spans, or bights, as in Fig. 2, and has, therefore, two terminal and seven intermediate stations.

Another plant is that of the Schaffhausen Water-Power Company, erected by J. J. Rieter & Co., and in operation since 1866. Its first cost was largely defrayed by a gift to the town of Schaffhausen from Mr. Moser, a public spirited citizen. Seven hundred and sixty horse-power are taken from the rapids of the Rhine; of this, 200 horse-power are delivered on the left bank of the river by means of shafting, while 560 horse-power are carried across the river by two equal wire cables, having each a span of 117.6 m., and a combined capacity of 530 horse-power (pulley rad. $R = 2250$ mm.; revolutions per minute $n = 180$), and a third smaller cable of 30 horse-power ($R = 900$, $n = 180$). On the right bank the line passes through a shunt (to borrow a term from electrical transmission), by which about 480 horse-power are diverted and sent up the river in three main sections, respectively 115.2, 101.4, and 138.9 meters long. The heavy ropes are composed of eight strands, each of ten wires, 1.85 mm. in diameter. Figure 3, representing a pillar for an intermediate station, is a model of good mechanical design. Two wheels are placed back of each other,

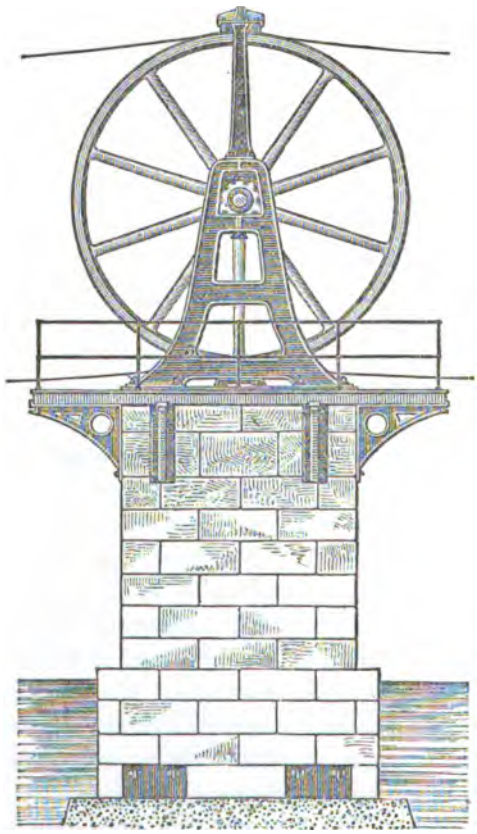
* The author here presented and explained to his audience a series of photographic views of large wire rope plants built by the J. J. Rieter & Co., of Winterthur, Switzerland, under the direction of their lately retired chief engineer, D. H. Ziegler.

For a few similar illustrations see *Transmission of Power by Wire Ropes*, by A. W. Stahl; Van Nostrand's Science Series, No. 28.—TRANS.

with a cross-piece set above them to prevent the ropes jumping out of the grooved rims, but in later constructions this piece has been omitted as unnecessary.

The turbine-wheel and wire-rope plant of the "Société Générale Suisse des Eaux et des Forêts," at Freiburg, Switzerland,—also built

FIG. 3.

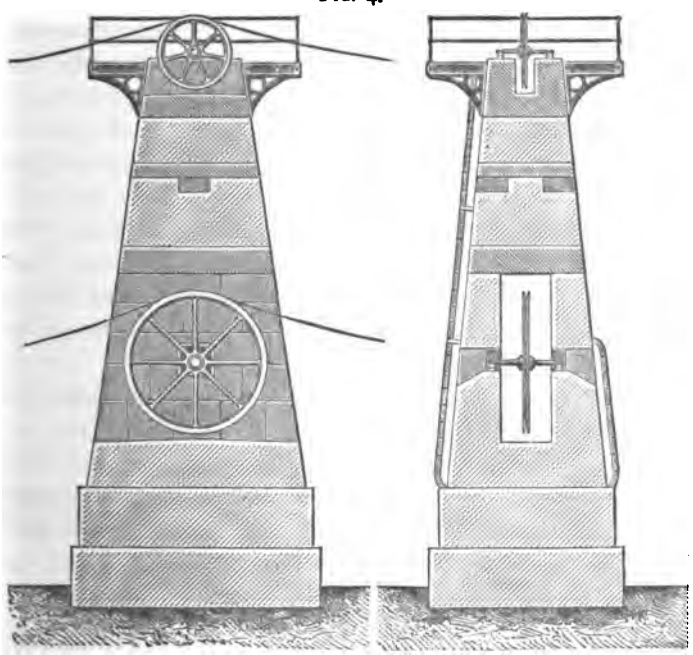


by Rieter & Co.,—takes from the Sarine at present about 600 horse-power, 300 of which are delivered by wire rope to a number of factories at a considerable distance from the source of power.* In its first three bights, each 153 m. long, the line rises 81.844 m. to the level of a sawmill. One of the tall piers required in this

* A plan is now projected, however, for conveying 2100 horse-power by four separate lines from the gorge of the Sarine up to the Perolles plateau.

stretch of the line is shown in Fig. 4; besides these, and further increasing the difficulties of the undertaking, one station in this section had to be located in a specially built tunnel. The rope here is composed of 10 strands, each of 9 wires, 1.8 mm. in diameter; for the pulleys $R = 2250$ mm., $n = 81$, and $v = 19$ m. At the sawmill a portion of the power is diverted by a shunt and an angle, or deflecting, station, while the balance is carried further with sundry changes of direction, and is finally delivered up at a

FIG. 4.



number of remote points. In addition to the 16-frame sawmill just mentioned, a wagon factory, foundry, fertilizer factory, and several smaller works are furnished with power. The total length of the line is 2010 m. To obtain and control the water-power involved the construction of a tremendous dam in the wild Sarine, and the blasting of a broad waste sluice out of solid rock, while the erection of the rope line required, as we have remarked, the driving of a great tunnel and the building of lofty masonry pillars, all of which entailed several years of hard work and heavy expenditure. How little such difficulties are appreciated in the me-

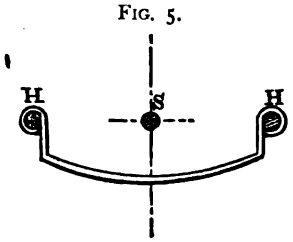
chanics of our popular weeklies appears from the light and ready way in which they treat of the creation of great water-powers in the mountains.

A fourth large water-wheel and wire-rope plant has been built by Rieter & Co. for the "Compagnie Générale de Bellegarde," to utilize the power of the well-known "Perte du Rhône." Five 630 horse-power wheels take from the Rhône and the Valserine 3150 horse-power, all of which can be delivered by the rope line upon the level of the Bellegarde plateau, though at present but a portion of it is used.*

In order to profit by the potential energy of the Limmat, the municipality of Zurich contracted with Escher, Wyss & Co. for the erection of a turbine and wire-rope plant. The total amount of work which the wheels are capable of taking from the river is 1150 horse-power, of which 900 are actually used—750 horse-power being consumed by the city water-works, while the balance, 150 horse-power, is transmitted by the rope line, and of this amount 80 horse-power are diverted laterally by means of shunts. The line is about 1 km. long; local conditions impose the use of very high standards which have been constructed, not of masonry, but of wrought iron.

Near St. Petersburg a former pupil of mine, Wischnegradski, has put up a wire-rope plant in ten sections for the use of the government powder works. From each of the ten stations, which are located around the enclosing wall of the works, a portion of the power is carried by a shaft through the wall into its respective working field.

FIG. 5.



Where a thoroughfare is crossed by a wire-rope line some sort of precautionary guard for the headway is usually required by the authorities. A very simple contrivance for this purpose has been introduced by Rieter & Co. Two fixed ropes, H, H (Fig. 5), are

* Engineering, 1874, vol. 37.

stretched beneath the moving cable S, and serve for the suspension of a number of wrought-iron stirrups, which are intended to catch the falling cable. The depth of the stirrups is ½ m., and their distance apart 3 m.

These brief descriptions will suffice to indicate the remarkable service which wire-rope lines can render as power transmitters, and to show that as such they already fill an important position in engineering practice. Such of the lines as exhibit the system on a grand scale display admirable constructive detail, and offer in each case a very fair solution of the problems presented. But still it would seem possible to introduce certain improvements into the system as a whole, especially where great power is to be sent over a long distance, and where, therefore, the line has to be subdivided into a considerable number of sections. In such cases the Ziegler system, with intermediate driving-wheels, has heretofore held the lead, as was fully warranted by the excellent results obtained; yet even this system bears certain inherent traits which militate against the more extended application of wire rope. To sum them up in a few words, they appear to be:

a. The great height usually required for the pillars, to which the necessarily large diameter of the pulleys contributes.

b. The unavoidable breadth of the pillars, as these have not only to keep the lower cord of the rope high above any thoroughfare level, but must also, in case they bear but one rope, withstand considerable pull in the direction of the line.

c. The necessity for very strongly built shunts, or switching stations, to support the heavy wheel work placed upon them.

d. The loss of power due to stiffness of cordage—a factor hitherto unconsidered, or, at least, underestimated, through lack of proper views on the rigidity of wire rope.

e. Interruptions of work caused by taking up the slack of stretched ropes.

f. The necessity for tightening up the ropes in the summer season (when heat naturally lengthens them) to such a degree that in winter they become undesirably taut.

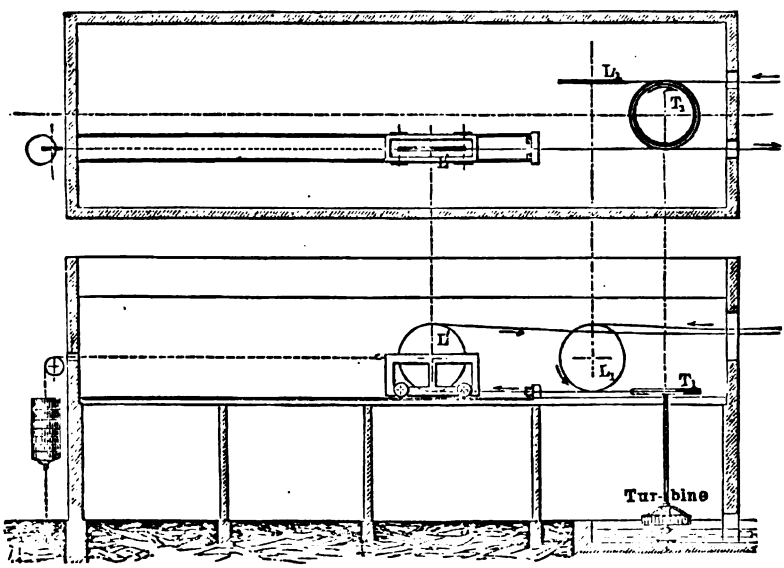
g. Nuisances arising from the spattering of the rope lubricant upon factory walls and on the ground about them when the driving-pulleys are set outside of the mills.

h. The necessity for using heavy intermediate pulley-wheels,

capable of withstanding the great stress of the tautened rope, and besides the loss of power occasioned by increased axle friction.

It would, therefore, be desirable to fix upon a disposition permitting the use of light and comparatively low supports, and affording, if practicable, automatic means for regulating the tension of the rope; it would further prove advantageous to reduce the number of splices, and place the driving-pulleys within the walls of the mill, where protecting aprons could easily guard against the spattering lubricants, and to employ, wherever possible, very light pulleys. All of these points may be secured in an eminent degree by adopting the following arrangements. In the

FIG. 6.



first place, the cable of the whole line should consist, so far as practicable, of one endless rope between the driving and driven pulleys, since in this way as many intermediate wheels as possible are reduced to mere bearing sheaves, which may be of very light design. In the next place, an obvious recommendation will be to suspend both the driving and the slack sides of the rope in the same level, at sufficient height above the ground for headway and no more.

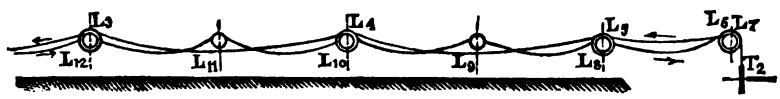
With this end in view in arranging the motor, or power, station of the line, we mount the first driving-pulley, T_1 (Fig. 6), horizon-

tally, if possible, upon the main power-shaft, or upon a counter driven by spur-gearing, and pass the taut, or driving, side of the rope around a fixed guide pulley, L_1, and thence either in horizontal or inclined direction out upon the first section of the line. The return, or slack, side is carried from the driver T_1 to a tension-pulley L′, the latter being mounted on a truck which has a horizontal travel in the line of the cable, and is drawn backward by a weight slightly greater than $2\ t$.

From this regulator the slack rope goes out upon the line in the same level with the driving rope. The truck and its guide tracks are shown under cover, assuming that the remaining room in the building is used for warehouse, shop, or watchman's quarters, but the whole regulating apparatus may be placed out of doors if desired.

The section, or intermediate, stations for both sides of the endless rope are now reduced to mere carriers, excepting only where a

FIG. 7.



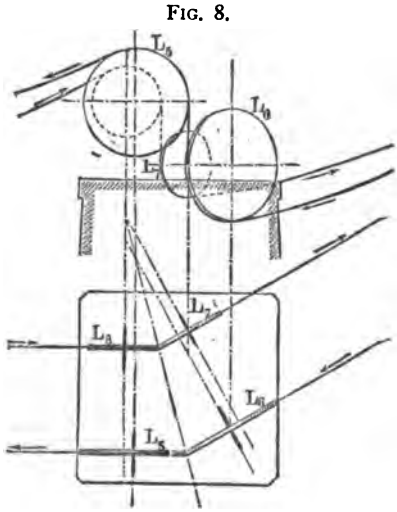
portion of the power is to be diverted at some point along the line. If the transmission is a normal one, then for the same depth of sag the driving side of the rope will have double the span, or bight, of the slack side, so that we obtain double and single wheel stations in alternation, as in Fig. 7. When no change occurs in the direction of the line the two branches of the rope run thus side by side, separated by the diameter of the pulley T_1, and so they enter the mill and pass there over fixed guide-wheels L_6 and L_7 to the driven wheel T_2, which is the main working pulley for the mill.

When the motor at the power station is shut down the driving-rope draws the tension regulator towards the turbine, since the tension in both sides of the line then becomes $\frac{1}{2}\ (T + t)$. The end of the track upon which the regulating truck travels can be fitted with buffers, and the bearers for the first guide pulley of the driving-rope L_1 may be set against an elastic cushion, and so furnish a suitable point for dynamometric observations. When the line is first set in motion the regulator L′ slowly recedes and imparts to the slack side of the rope its proper tension t. The more

the rope stretches in the beginning the further backward does it displace the play of the regulator, and the buffers may be correspondingly moved back. When the limits of this play are reached the rope has to be shortened and respliced. The rope is subject to less stretching in this system, however, than where intermediate drivers are used, as there are fewer bends around the pulleys. This feature reduces the wear of the rope, and so contributes materially to its life.

If deflecting stations are required in the line, an arrangement of the pulleys, as indicated in Fig. 8, will effect the purpose. Only

FIG. 8.



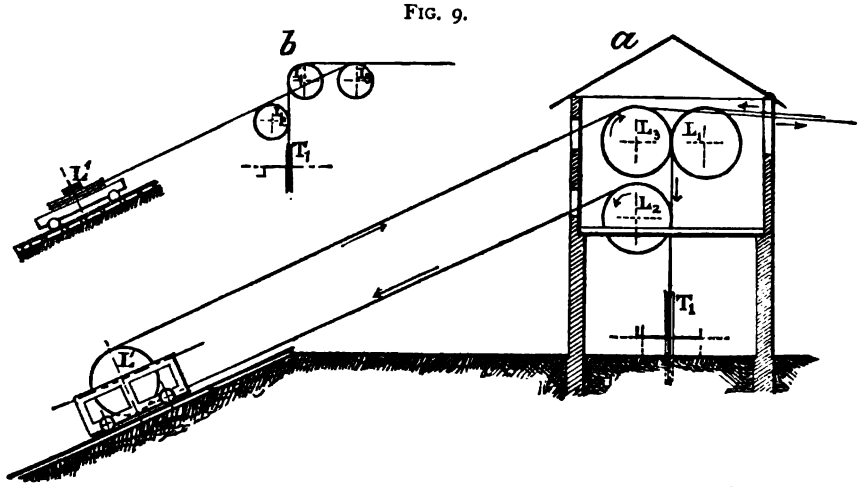
two wheels are required for each branch of the rope and all gearing with its attendant, and by no means inconsiderable, loss of power is dispensed with.

When from the nature of the case the first driving-pulley T_1 at the power station has to be set vertically instead of horizontally, the arrangement outlined in Fig. 9, *a*, may be adopted, involving the use of one additional guide-wheel. The figure shows also how an inclined track may be utilized for the regulator, the truck itself being properly loaded to produce the tension. Fig. 9, *b*, illustrates a very similar disposition, in which, however, the pulley L′ lies upon the counterpoise truck instead of being mounted vertically.

If the main working-pulley in the mill, T_2, is to be in the same

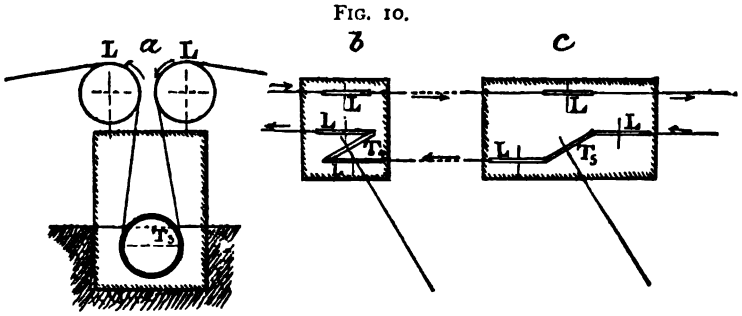
plane with one of the sides of the endless rope, it is only necessary to deflect the other side toward it by means of a simple angle station. In long lines with great numbers of bearing standards the ease with which the above-described angle, or deflecting, station can be established, enables us to bring the two sides of the rope as near together as may be desired without the least difficulty.

FIG. 9.



The shunts are reduced to much simpler forms than in the older system by discarding, as for the angle stations, all cumbrous toothed gearing, and simply adopting some such device as drop-

FIG. 10.

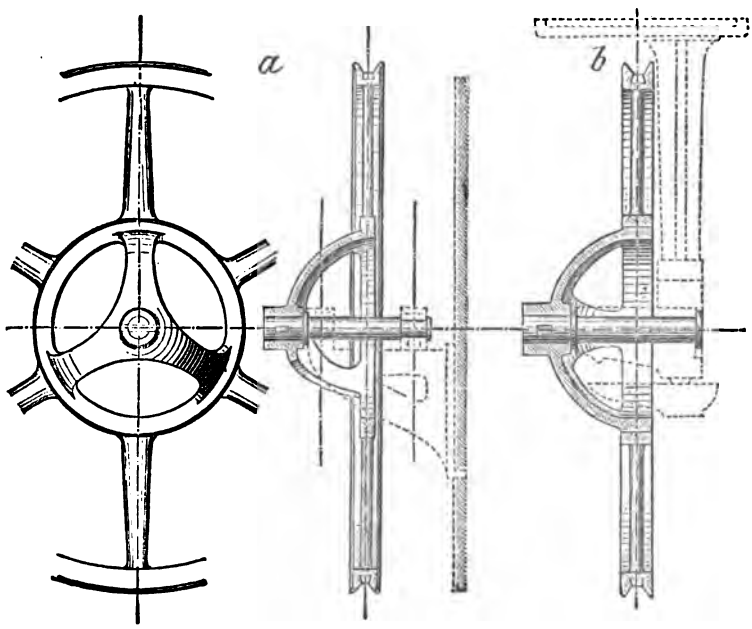


ping the axle of the shunting-wheel, and thus allowing the latter to be set at any angle to the main line, as in Fig. 10, *a*, *b*, *c*.

The forces acting upon the simple carrying sheaves are so insignificant that wrought-iron wheels of merely trifling weight will

answer. But if light cast-iron pulleys are preferred, it would be an improvement in their design to place the hub of the wheel beyond the two journals, as in Fig. 11, *a*, while its medial plane should still cut the line of the axis between the journals. A casting shaped somewhat like a cowl will then be required to connect the spokes with the hub, a characteristic which leads me to suggest

FIG. 11.



the name of *cowled pulley** for this new form. An advantage of the cowled wheel lies in the peculiar mode of mounting it, by which one of its sides is kept entirely free without bringing unequal or opposite stresses to bear upon the journals. Fig. 11, *b*, illustrates a wheel with straight spokes, and a separate cowled spider which may be fitted to wrought or cast wheels of various diameters. The two journals are united into one long one, as shown, and this rests in a solid bearing, indicated by dotted lines.

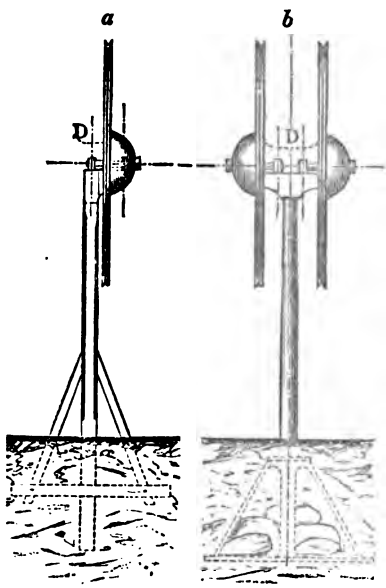
By the use of the cowled wheel the construction of the stations becomes very much simplified. In Fig. 12, *a*, we see a one-wheel bearing station with a wooden post, and in Fig. 12, *b*, a two-wheel

* *Schirmrolle.*

station with an iron standard. In each design the upright carries a bearing bracket, which extends into the cowl (the latter appearing unbroken, instead of open, in the figure, merely because it is drawn to so small a scale); while a light cover plate, D, shown in dotted lines, serves to protect the bearings.

A comparison of this station with one of the older type, *e. g.*, the one illustrated in Fig. 4, reveals at once the structural facilities

FIG. 12.

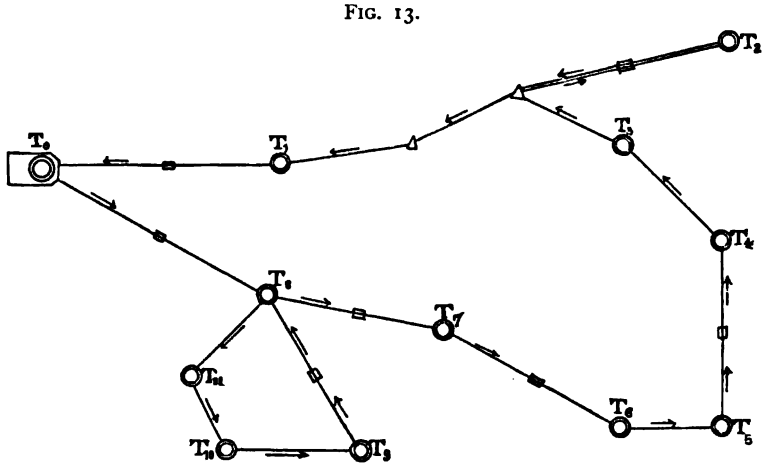


which can be derived, both separately and jointly, from the newer system of transmission and the cowled pulley.

An interesting question yet to be considered is the tension of the driving-rope after having passed through a number of shunting stations. If at such points it parts successively with tangential forces, P_1, P_2, P_3, etc., its initial tension T will be diminished by these several amounts—a fact which must be taken into account in determining the sag of the line in the bights preceding and following each shunt. Every diversion of power, then, effects a change in tension; the sum of all the P's, however, added to the tension t in the slack side of the rope at the first driving-pulley of the line, must be equal to the original T, or $T - t = \Sigma P$, so that our former consideration of the values of T and t remains unal-

tered. But this suggests important deductions, for if we carry the principle of diverting power at shunting stations to its legitimate end, we can distribute through such points the whole working energy of the line, and so obtain a plant in which a single rope travels over the entire dynamic field, as the diagram (Fig. 13) would indicate. The rope starts from the power station under any angle with a tension t; it gives up power at the points T_1, T_2, T_3, etc., to T_{11}, and after covering in its course the complete working

FIG. 13.



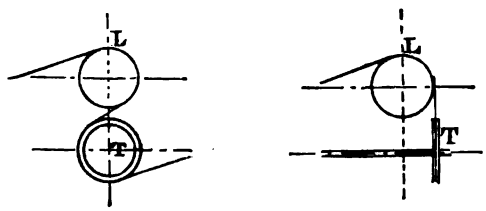
circuit, finally re-enters the first station under a tension $T = \Sigma P + t$.

All the tensile stresses of the different bights are automatically controlled, including such fluctuations as may arise from varying, or possibly interrupted, demands for power. For should the effort deliverable at any point drop, even to zero, the regulator at the power station would immediately accommodate itself to the change; that is, in this case, it would advance, and increase the slack of the rope in proportion to the diminishing tension, always maintaining the relation $T - t = \Sigma P$, in which t is constant. This system of transmission in which the rope passes through a circuit of working points I propose calling *circuit rope transmission*.* In the diagram the stations at which power is delivered are marked by circles, while the simple bearing stations are represented by small rect-

* *Kreisseiltrieb.*

angles or triangles, according as they occur in straight or broken stretches of the course. The manner of deflecting a subordinate circuit from the main one, forming, as might be said, a dynamic circuit of the second order, is shown at T_8. The stations can all be of the simplest kind: bearer stations in straight sections of the circuit need but one pulley, and at angles but two. For delivery stations two pulleys usually suffice, both in straight and broken sections of the course (Fig. 14) if the arc of contact is sufficiently large; if it is not, three wheels are required. Sometimes the conditions may be favorable for placing the rope under ground, as in Fig. 15. To determine for any case whether a given arc of contact is suffi-

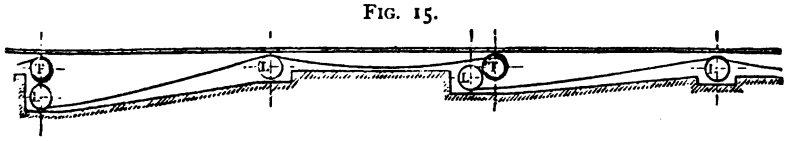
FIG. 14.



ciently large, we have, as before, for the maximum effort P, which the pulley can take from a rope stretched to a tension T', $P = T' \div \tau$, and this we can readily apply to each individual case, and so arrive at favorable proportions.*

Turning our attention now to the application of circuit transmission within the narrower limits of a single mill, the possibility of substituting this system for the method of driving with hemp

FIG. 15.

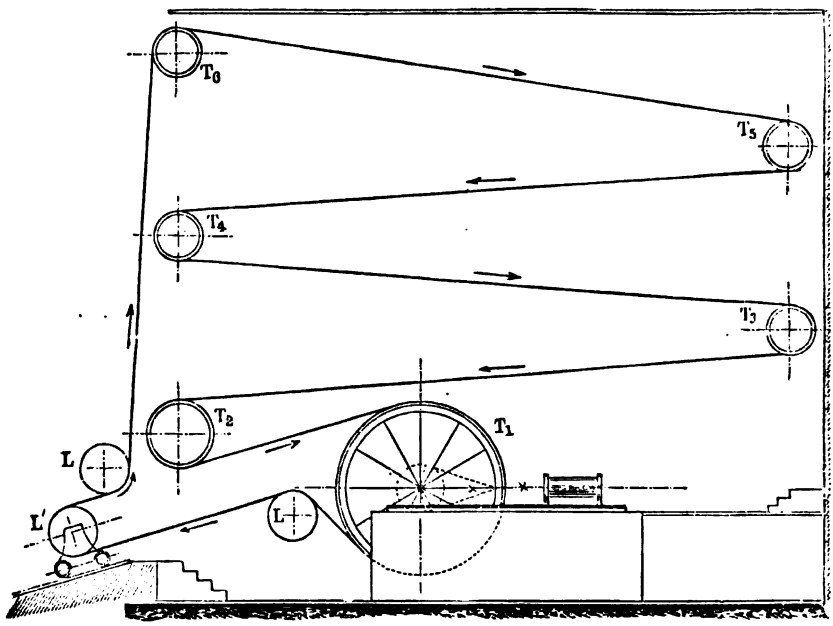


rope, so much in vogue at present, will at once be suggested. Fig. 16 shows the proposed arrangement: a single wire rope is driven by the main fly-wheel T_1, and imparts its effort to five line pulleys, T_2, T_3, etc., to T_6. L, L are guide-pulleys, and L′ a tension regulator, mounted upon a counterpoise truck. In many

* See author's Konstrukteur, 4th edition, p. 835.

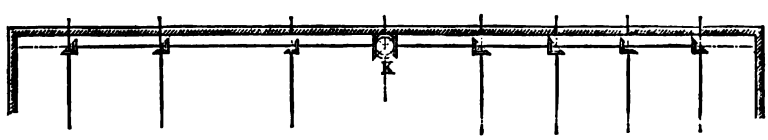
factories the use of wire rope in a dynamic circuit must lead to much simpler mounting of the shafting than has hitherto been possible with toothed, and generally bevelled, gearing. Fig. 17 is an example from actual practice of shaft transmission in a weaving

FIG. 16.



mill. Through two line-shafts, taking power from K, seven cross-shafts are driven by seven pairs of wheels.* Fig. 18 illustrates how the longitudinal line-shafts may be replaced by a wire rope

FIG. 17.

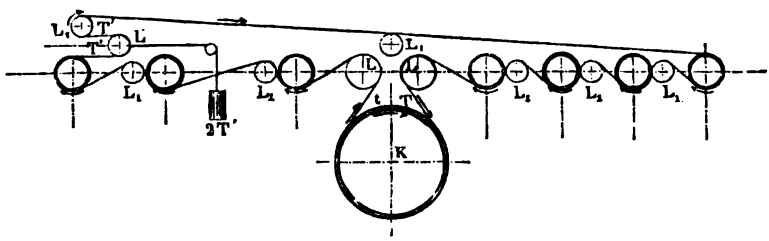


circuit, in which seven drivers, nine guide-pulleys, and one tension, or stretcher, pulley L′ are used. The guide-wheels may all be of the cowled pattern (Fig. 11). The tension-pulley, owing to its position in the dynamic train, is weighted with a load $2T$.

* In factories where spinning and weaving are placed on one floor from 12 to 18 cross-shafts are more common.

In Fig. 19 another solution is offered, based on the assumption that the cross-shafts may be driven alternately to the right and left. Of the seven driving-pulleys, five are double-acting and hence require two grooves each. Parallel shafts, lying vertically

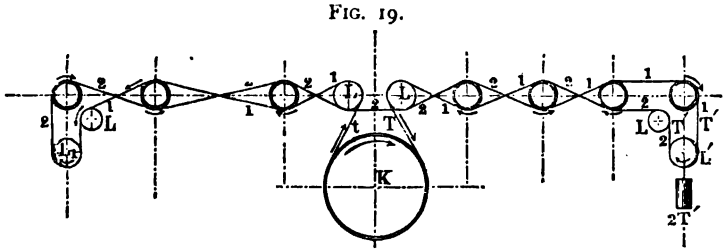
FIG. 18.



above one another, are generally connected for power transmission by means of a vertical shaft; here, too, a rope circuit may be profitably substituted for the older system.

In case it be required to drive a number of parallel counter-shafts, which are to revolve both to the right and to the left and are to run or be idle, as occasion demands, circuit transmission may sometimes be very suitably adapted, as suggested in Fig. 20. The wire rope runs over a series of pulleys and then, passing around a stretcher L', returns over a second series. At K_1 and K_2 friction-couplings would have to be introduced, set respectively for positive and negative rotation. Should it be desired to drive

FIG. 19.

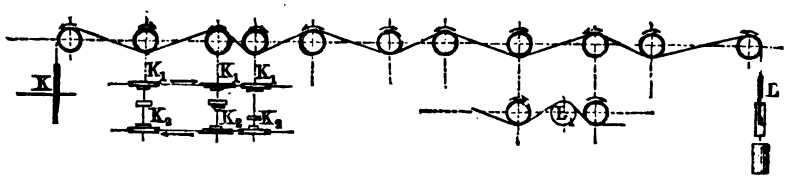


two successive counters of the series in the same direction, this could readily be accomplished by intercalating a guide-wheel, as shown at L_1. With such a general disposition as this, the arrangement of the driving-belts which run down from the counter-shafts becomes exceedingly simple.

Finally there are cases in which machines with horizontal power

shafts may be advantageously driven by a rope circuit, particularly where a number of them are set up in a regular series (Fig. 21), and each requires considerable power (*e. g.*, grist mills, pulverizers, etc.). To throw them in and out of work friction-clutches K_1 K_1 can be used; the guide-pulleys L L under the ceiling may be of the cowled type, mounted on light pendent brackets, while for the protection of workmen the travelling rope should be guarded by fenders S. The above arrangement would prove especially suitable where a second series of machines was similarly disposed in an upper floor of the mill, for then the upper row of driving-wheels would take the place of the guide-pulleys, and all hanging gear could be dispensed with. Under certain circumstances it would be advisable to mount the driving-pulleys (which may be made of the cowled pattern) upon separate small pillow-blocks, turning the

FIG. 20.



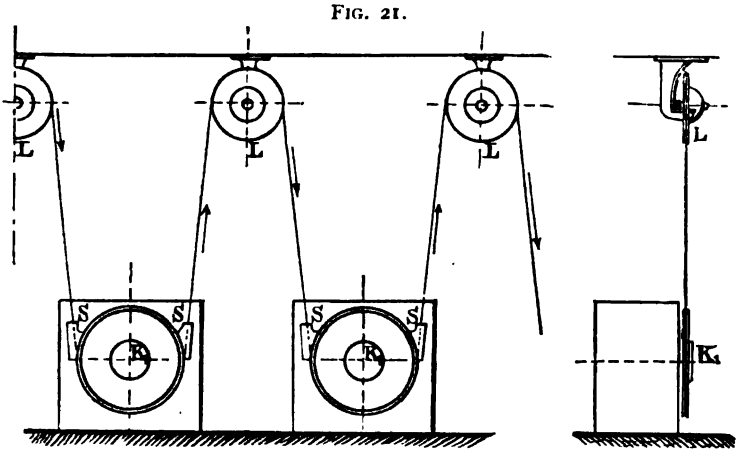
faces of the wheels away from the machines, as has been indicated in Fig. 20. This would secure free access to all parts of the machine for examination and repairs, and even for complete renewal, without interrupting the general running.

In considering the merits of the above described application of wire rope in a dynamic circuit, it should be duly observed that to realize the full advantages of the system the whole arrangement of the mill must be planned for it at the time of building, though exceptional instances may occur where the necessary alterations for substituting a rope circuit in place of shaft transmission would be warranted.

I have thus attempted to show that wire rope applied in circuit can meet in a very advantageous manner not only the requirements of a teledynamic transmitter—more especially where power is to be delivered at a great number of points—but that it answers equally well for the conditions of short distance transmission, and passes with the retention of the characteristic stretcher pulley into the older form of rope transmission. Compared with the older

system, the newer one presents far less obstacles in the erection of large plants; its first cost is much less, and its maintenance easier. There is every prospect, therefore, of a wide extension in the range of its application; and it seems, too, as if this system

FIG. 21.



were well fitted to cope successfully with the rival methods of electro-dynamic transmission which have recently been appearing, all the more for the reason that these latter, by converting mechanical power into current, and current again into power (high velocity into a low velocity, and the low one again into a high one), occasion serious losses of useful work, and require very expensive converting machines.

(To be continued.)

ON THE ACTION OF HYDROFLUORIC ACID ON SILICA AND SILICATES.*

BY J. B. MACKINTOSH.

IN a preliminary note on this subject published in July,† I called attention to the great difference in the behavior of quartz and opal, when submitted to the action of hydrofluoric acid, and gave a general indication of the behavior of silicates under similar circumstances. The few data contained in the above-mentioned note will all be included in the present paper, which I hope may

* Read before the American Chemical Society, November 5, 1886.

† School of Mines Quarterly No. 4, Vol. 7.

be regarded as an acceptable contribution to the literature of the silicates.

The starting point of the present investigation arose from a question which occasionally presented itself in the course of my professional work. I have frequently been appealed to to decide on the identity of cut and polished gems without, of course, subjecting them to injury in any way. Chemical analysis being out of the question, it is necessary to make the determination by means of the physical characteristics alone, but in certain cases it becomes a very difficult matter to decide. The two gems garnet and spinel occurring in varying shades of color, although generally readily distinguished, yet occasionally approach so closely in their characteristics that I attempted to find a means of differentiation based on their chemical constitution which, while it would have the certainty of a qualitative analysis, would leave the gem practically uninjured. Since spinel is a compound of a protoxide with a sesquioxide in equal molecular proportions, while garnet is a silicate which may be regarded as derived from spinel by the substitution of an equivalent amount of silica for two-thirds of the sesquioxide present, it seemed probable that hydrofluoric acid would furnish the means of differentiation sought for; but on making the experiment it was found that neither mineral was attacked in the slightest degree. This unexpected result was so interesting that I determined to extend the investigation further than I had originally purposed, and to examine in this way the principal silicates occurring in nature.

The following tables show the results of the qualitative experiments I have made. I have included in these tables the atomic formulæ, the specific gravity, the unit-volume and the percentage of silica in the mineral. For the first three data I am indebted to Dr. T. Sterry Hunt, and have taken most of them from his recently published essay on "A Natural System of Mineralogy, with a Classification of Native Silicates."*

The atomic formulæ are those employed by Sterry Hunt, and differ from ordinary formulæ in that the quantities represented by the symbols of the elements are all equivalent to one atom of hydrogen. The coefficients thus represent the oxygen ratios of the constituents, and the formulæ are very much simplified.

* This essay forms pages 279-401 of his Mineral Physiology and Physiography, 1886. Samuel E. Cassino, Boston, Mass.

I.—MINERALS WHICH ARE VISIBLY ETCHED BY HYDROFLUORIC ACID.

	Atomic Formula.	Sp. Gr.	Volume	% SiO_2.	Remarks.
Quartz	$si_1 o_1$	2.67	5.62	100.	very slightly attacked.
Opal	$si_1 o_1$	2.2	6.81	100. ?	H_2O regarded as non-essential.
Petalite	$(li_1 al_4 si_{20}) o_{25}$	2.42	6.38	78.	
Wollastonite	$(ca_1 si_1) o_3$	2.92	6.62	51.7	
Rhodonite	$(mn_1 si_1) o_3$	3.63	6.06	46.7	
Tremolite	$((mg\frac{3}{4} ca\frac{1}{4}) si_1) o_3$	2.97	5.88	57.4	very slightly attacked.
Willemite	$(zn_1 si_1) o_3$	4.18	6.63	27.5	
Chrysolite	$(mg_1 si_1) o_2$	3.40	5 38	45.	
Fayalite	$fe_1 si_1) o_2$	4.35	5.86	27.3	very slightly attacked.
Wernerite	$(m_4 al_9 si_{16}) o_{39}$	2.70	6 44	48.5	
Vesuvianite	$(ca_9 al_9 si_5) o_{10}$	3.40	5 67	37.	very slightly attacked.
Biotite	$(mg_4 al_4 si_3) o_{16}$	3.00	6 06	41.	very slightly attacked.
Phlogopite	$(mg_4 al_2 si_3) o_{12}$	2.85	6 35	40.	very slightly attacked.
Iolite	$((mg\frac{2}{3} fe\frac{1}{3}) al_3 si_5) o_9$	2.67	6.31	49.	
Albite	$(na_1 al_2 si_{12}) o_{16}$	2.62	6.24	68.6	
Orthoclase	$k_1 al_3 si_{12}) o_{16}$	2.54	6 88	64.6	
Oligoclase	$((na\frac{3}{4} ca\frac{1}{4}) al_3 si_9) o_{12}$	2.65	6.27	61.5	
Labradorite	$((ca\frac{3}{4} na\frac{1}{4}) al_3 si_6) o_{10}$	2 70	6.28	55.5	
Leucite	$k_1 al_3 si_9) o_{12}$	2.56	7.09	55.	
Titanite	$(ca_1 si_2 ti_2) o_5$	3.50	5.65	30.5	
Datolite	$(ca_2 si_4 b_2 h_1) o_{10}$	2 99	5.35	37.5	very slightly attacked.
Apophyllite	$(ca_1 si_4) o_8 + 2$ aq	2.35	6.44	53	
Pectolite	$(ca_2 si_{13}) o_{17} + 1$ aq	2.78	6.57	54.6	
Calamine	$(zn_2 si_1) o_3 + \frac{1}{2}$ aq	3 50	6 87	25.	
Prehnite	$(ca_2 al_2 si_6) o_{11} + 1$ aq	2.95	5.64	43.6	etched with difficulty.
Henlandite	$(ca_1 al_2 si_{12}) o_{16} + 5$ aq	2.20	6.58	59.	
Stilbite	$(ca_1 al_2 si_{12}) o_{16} + 6$ aq	2.20	6.46	57.4	
Harmatome	$(ba_2 al_2 si_{10}) o_{16} + 5$ aq	2.45	6.82	46.5	
Chabazite	$(ca_1 al_2 si_4) o_{12} + 6$ aq	2.19	6 41	52.2	
Analcite	$(na_2 al_2 si_4) o_{12} + 2$ aq	2.29	6 86	54 5	
Natrolite	$(na_2 al_2 si_3) o_{10} + 2$ aq	2.25	7.08	47.3	
Serpentine	$(mg_3 si_4) o_7 + 2$ aq	2.53	5 78	42.	
Halloysite	$(al_2 si_4) o_7 + 3$ aq	2 40	5.75	43.3	
Jeffriesite	$(mg_6 al_6 fe_2 si_{15}) o_{30} + 7\frac{1}{2}$ aq	2.30	6.50	34.	

II.—MINERALS WHICH ARE NOT VISIBLY ETCHED BY HYDROFLUORIC ACID.

	Atomic Formula.	Sp. Gr.	Volume	% SiO_2.	Remarks.
Quartz	$si_1 o_1$	2.67	5.62	100	some varieties.
Enstatite	$(mg_1 si_1) o_3$	3.10	5 54	60.	
Diopside	$((mg\ ca)_1 si_2) o_3$	3.28	5.48	54.	
Spodumene	$(li_1 al_4 si_{20}) o_{15}$	3.18	4.88	64.	
Beryl	$(be_3 al_2 si_{12}) o_{18}$	2.70	5 52	67.	
Tremolite	$(mg\frac{3}{4} ca\frac{1}{4} si_2) o_3$	2.97	5.88	57.4	slightly attacked by long exposure.
Zircon	$(zr_1 si_1) o_3$	4.70	4.84	33.	
Garnet	$(ca_3 al_1 si_3) o_4$	3.50	5 37	36.	
Epidote	$(ca_2 al^4/_3 h^2/_3 si_3) o_6 + \frac{1}{3}$ aq.	3.40	5.40	38.	
Zoisite	$(ca_2 al_3 si_3) o_6$	3.35	5.32	41.	
Axinite	$(ca_2 al^4/_3 h^2/_3 b^1/_3 si_3^1/_3) o_7$	3.27	5.53	44.	
Danburite	$(ca_1 b_2 si_4) o_8$	3.00	5.12	48.	
Lepidolite	$(m_1 al_4^1/_3 si_3) o_{12}^1/_3$	3.00	5 61	46.5	
Muscovite	$(k_1 al_6 si_3) o_{16}$	3.12	5.68	46 5	
Biotite	$(m_4 (al\ fe)_4 si_3) o_{16}$	3.00	6.06	41.	very slightly attacked.
Phlogopite	$(m_4 al_2 si_3) o_{12}$	2.85	6 35	40.	very slightly attacked.
Fayalite	$(fe_1 si_1) o_2$	4 35	5 86	27.3	very slightly attacked.
Tourmaline	$(m_1 al_3 si_3) o_9$	3 05	5.36	37.5	
Andalusite	$(al_2 si_1) o_5$	3.35	4.83	37 5	
Cyanite	$(al_2 si_1) o_5$	3.66	4.42	37.5	
Topaz	$(al_2 si_1) o_4 f_1$	3.65	5.04	34.	
Datolite	$(ca_2 si_4 b_2) o_9 + 1$ aq	2.99	5 35	37.5	forms coating of $Ca F_2$.
Prehnite	$(ca_2 al_2 si_6) o_{12} + 1$ aq	2.95	5.64	43 6	slightly attacked.
Talc	$(mg_4 si_{10}) o_{14} + 1$ aq	2.60	6 07	62 8	
Ripidolite	$(mg_6 al_2 si_3) o_{14} + 4$ aq.	2.70	5.70	31 3	
Margarite	$(ca_1 al_6 si_4) o_{17} + 1$ aq.	2.99	5 54	30.	

To the above may also be added the non-silicate species corundum, spinel and chrysoberyl, which are not attacked, and the artificial product glass, which is.

I have included in both classes several species which seem to be on the border line, and which sometimes seem to be unattacked, while at other times by longer exposure or by treatment of a different surface a slight action becomes evident. Thus with vesuvianite, the prism faces of a crystal showed no etching, while the basal plane of the same crystal was perceptibly attacked; this, however, might have been due to a difference in the time of exposure, though in other cases, as in quartz, it is undoubtedly the fact that some surfaces are not attacked as readily as others.

By inspection of the data given it will be seen that the amount of silica present does not determine the action of the acid, nor does the molecular ratio of silica to the bases, but we see that the volumes show a very decided difference. In the non-attacked species, the volume of the greater number is considerably below 6, while in the non-resisting species it is generally considerably above this figure. Thus comparing enstatite and diopside with wollastonite and tremolite, we have in the first two, volumes of 5.54 and 5.48, in the less dense wollastonite the volume is 6.62 while the tremolite has an intermediate volume of 5.88, and it is likewise intermediate in its relation to the acid. These four minerals differ in composition mainly by the gradual substitution of lime for magnesia, the ratio of bases to silica remaining unchanged. It is possible that the nature of the base may have a considerable effect on the extent of condensation of the molecule. In the above instances the replacement of magnesia by lime seems to tend to increase the volume and diminish the power of resistance to HF.

At the suggestion of Dr. T. Sterry Hunt, while carrying on these qualitative tests, I also proceeded to make quantitative comparisons of several minerals. I proposed to use quartz as a standard of reference, but immediately found it was so slightly attacked that it would not do for the purpose.

In these experiments the minerals were reduced to an average size of 3-100 cubic millimeter by careful sizing, and one gram of each sample was taken for each experiment. The samples were all treated for an hour with an excess of dilute hydrofluoric acid (9 per cent.) at the ordinary temperature of the laboratory, all conditions being as far as possible the same; at the expiration of

that time the acid was poured off, the residues carefully washed and dried, and where any insoluble fluorides or products resulting from the decomposition of the mineral were present, they were removed by the use of a fine bolting-cloth before weighing the residue of unattacked mineral. The results obtained are given in the following table, which also shows the atomic formula, the density, the volume and the per cent. of SiO_2 for each mineral:

QUANTITATIVE RESULTS.

	Atomic Formula.	Sp. Gr.	Volume.	% SiO_2	% Dissolved.	
Quartz	$si_1 o_1$	2.67	5.62	100	1.56	
Tremolite	$(mg_{\frac{4}{5}} ca_{\frac{1}{5}} si_2) o_3$	2.97	5.88	57.4	2.47	Governeur, N. Y.
Augite		3.30	....	....	2 61	Note 1.
Hornblende		3 21	....	....	2.64	Note 1.
Chrysolite	$(mg_1 si_1) o_2$	3.40	5.38	45.	5.40	
Prehnite	$(ca_2 al_2 si_3) o_{11}+1$ aq	2.95	5.64	43.6	8.59	Paterson, N. J.
Albite	$(na_1 al_2 si_{12}) o_{16}$	2.62	6.24	68.6	23.1	
Labradorite	$(ca_{\frac{3}{4}} na_{\frac{3}{4}} al_2 si_3) o_{10}$	2.70	6.28	55.5	24.65	Note 2.
Petalite	$(li_1 al_4 si_{20}) o_{35}$	2.42	6.33	78.	28.97	Sweden.
Oligoclase	$((h\,ca)\,\frac{1}{4}\,na^{3}_{4}\,al_2 si_{10}) o_{14}$	2.61	6.41	64.26	35.25	Haddam, Ct.
Orthoclase	$(k_1 al_2 si_{12}) o_{16}$	2.54	6.83	64.6	43.45	Pike's Peak, Colorado
Iolite	$(mc^{2}_{3}\,fe^{1}_{3}\,al_2 si_5) o_9$	2.67	6.31	49.	47.34	Finland, Note 3.
Oligoclase	$(na^{3}_{4}\,ca^{1}_{4}\,al_2 si_9) o_{13}$	2.65	6.27	61.5	50 83	Sweden.
Nephrite		....	....	....	61.59	Easton, Pa., Note 4.
Leucite	$(k_1 al_2 si_8) o_{12}$	2.56	7.09	55.	66 30	
Rhodonite	$(mn_1 si_2) o_3$	3.63	6.06	46.7	69.21	Franklin, N. J.
Opal	$si_1 o_1$	2.2	6.81	100.	77.28	
Serpentine	$(mg_3 si_4) o_7+2$ aq	2.53	5.78	42.	80 67	
Halloysite	$(al_2 si_4) o_7$	2.40	5.75	43.3	100.0	Lookout, Ala., Note 5.
Willemite	$(zn_1 si_1) o_2$	4.18	6.63	27.5	100.0	Franklin, N. J.

Two samples of willemite were also treated for fifteen minutes, with the following results:

Green Willemite, massive,	86.78
Brown Willemite, crystallized (troostite),	92.09

Note 1.—These samples of augite and hornblende are from Teplitz, Bohemia. I have not their analysis.

Note 2.—The surfaces of the grains were coated with a white incrustation, probably of fluoride of calcium, which would both retard the action of the acid and make the apparent amount dissolved less than the truth; both causes of error acting in the same direction.

Note 3.—A fine powder insoluble in HF was formed—either an insoluble fluoride or an included mineral.

Note 4.—This so-called nephrite, said to be a variety of amphibole, is from Easton, Pa. Dana says it is a mixture of minerals. The result I have obtained shows that it is certainly not amphibole, nor does it contain much, if any, of that species.

NOTE 5.—This disintegrated with great rapidity, but left an insoluble residue behind, either an insoluble product of the reaction or an included mineral.

Now, on comparing together minerals of like formula in this table, we will see that the one with least volume is likewise least attacked by the acid—for instance, quartz and opal, tremolite and rhodonite, chrysolite and willemite, albite and orthoclase. Taking together the different feldspars and minerals of analogous composition, although they are not strictly comparable on account of the variation in the amount of silica, we have the series in order of solubility: Albite, labradorite, petalite, oligoclase, orthoclase, oligoclase, leucite; which, with the exception of the second oligoclase, is also the order of increase of volume. It is of course to be expected that variations in composition will have a great influence in modifying the action of the acid; but oligoclase seems to be exceptional, as it is intermediate in composition between albite and labradorite, and we would expect its solubility to be between them also.

The oligoclase which gave me a solubility of 50.83 per cent. was from a Swedish locality, but I could not obtain its analysis. On account of the discrepancy in this result with what we should expect, I obtained from Prof. B. W. Frazier, of Lehigh University, a sample of oligoclase from Haddam, Conn. (the first one in the table), which gave a solubility of 35.25 per cent.—a specific gravity of 2.61 and a volume of 6.41. The analysis of oligoclase from this locality (Dana's system, p. 347) leads to an atomic formula differing slightly from that given by Dr. Hunt, but agreeing with that given by Dana. This result takes its place in the proper order according to volume, and I think leaves no doubt that the volume accorded to the 50.83 per cent. oligoclase is erroneous. This experiment was made at a different time, and under slightly different conditions, so that the solubility found is probably rather less than it should be.

To further illustrate the subject, I obtained a sample of slag from an iron cupola-furnace, the outside portion being vitreous from sudden cooling while the interior was opaque and crystalline. The composition of the two portions being presumably the same, as the piece chosen was but the size of a fist, any variation in solubility could only be ascribed to the molecular condition, and not to any difference of composition. The crystalline portion was

very porous, it having an apparent specific gravity in the lump of 2.34, but on pulverizing finely, though not to an impalpable powder, the density rose to 2.97. The vitreous portion changed less—from 2.77 in lump to 2.81 in powder.

The results obtained for solubility in 9 per cent. hydrofluoric acid were:

	Sp. Gr.	Volume ratio.	Per cent. dissolved.
Vitreous slag	2.81	1.057	68.80
Crystalline slag	2.97	1.	9.60

This result also agrees perfectly with what might be expected.

M. W. Iles, in a paper on "The Decomposition and Analysis of Slags,"* describes a method of obtaining samples of slags for analytical purposes by chilling the melted slag suddenly, thus obtaining a vitreous sample, which is readily soluble in dilute hydrochloric acid; while if allowed to cool and become crystalline it is not attacked by the acid. This is a practical application of the law of increase of solubility with increase of volume, set forth by Sterry Hunt, in 1863, when he asserted in comparing the silicates meionite and zoisite, that "The augmentation of hardness, of density, and of chemical indifference, which is seen in this last species, is doubtless to be ascribed to a more elevated equivalent; or, in other words, to a more condensed molecule." Again in 1867, he wrote, after naming a number of groups of related minerals, "The hardness of these isomeric or allotropic species and their indifference to chemical reagents, increases with their condensation; or, in other words, varies inversely as their empirical equivalent volume, so that we here find a direct relation between chemical and physical properties." This is resumed in his concise statement that, "In related and homologous species the hardness and chemical indifference are inversely as the value of *V.* (the so-called atomic volume); or, in other words, that they increase with the diminution of *V.*"† The specific gravity of solids and liquids is, according to Sterry Hunt, a function of their equivalent weights.

* School of Mines Quarterly, Vol. 5, p. 351.

† Comptes Rendus de l'Académie des Sciences, lvi. 1256; Hunt's Chemical and Geological Essays, pp. 446, 457; and Mineral Physiology and Physiography, p. 304.

In order to test still further the truth of this law I ignited several samples of the granulated quartz used in the previous experiments, for varying periods of time, anticipating that the longer the period of ignition the greater would be the solubility, since we know that fused quartz has a lower specific gravity than the original crystal. The results were extremely satisfactory, and are as follows:

INFLUENCE OF IGNITION ON THE SOLUBILITY OF QUARTZ.

One grm. of each sample treated for one hour with excess of dilute (9%) HF.

	Per cent. dissolved.	Sp. Gr.
Raw quartz	2.18-1.28	2.64
Same, ignited over Bunsen burner 30 minutes	1.61	
" " " " " 45 "	1.78	
" " " " " 75 "	1.87	
" " " " " 120 "	2.05	
" " " " " 75 " and over blast lamp 45 minutes	4.23	2.62
" " " blast lamp 120 "	2.79	
" " " " " 210 "	5.35	
Fused quartz	11.02	2.22

I obtained the sample of fused quartz through the kindness of Dr. T. Sterry Hunt, who prepared it in the electrical furnace of the Messrs. Cowles, at Cleveland, Sept. 1st, 1885.* The sample taken was treated for an hour and a quarter, at the same time as a sample of ordinary quartz for comparison. In that time it had lost 13.77 per cent. against 2.13 per cent. for the raw quartz. In the table I have deducted one-fifth this amount, so as to give the solubility in one hour, which permits direct comparison with the other determinations. The solubility of the raw quartz, I find, varies in different determinations. I have, in all, obtained the following values: 1.28, 1.56, 1.70, 1.70, 2.18. The last figure is probably too high, from mechanical loss.

Although the temperature of ignition is far too low to effect fusion, the results show that a molecular change has commenced towards the less dense and more easily soluble form of silica. In this connection, I attempted to prepare some tridymite by the fusion of amorphous silica with metaphosphate of sodium, and obtained thin plates which were readily soluble in the acid. I had not enough material to make other than the one test, and

* Trans. A. I. M. E., Vol. xiv., p. 492.

only surmise that it really was tridymite, though probably an impure sample.

The action of quartz being so interesting, I made several experiments on whole crystals of different crystalline modifications, from three localities, in order to ascertain the quantitative differences between them, since I had noticed in my qualitative tests that some quartz crystals did not show any appreciable etching action. As in these cases the amount of action depends on the surface exposed, I have measured the area of the exposed faces, protecting broken surfaces, and certain faces, with wax, unless otherwise mentioned.

TREATED FOR ONE HOUR IN 9 PER CENT. HYDROFLUORIC ACID.

	Locality.	Weight. Grams.	Amount Dissolved.		Area of Faces. Square Centimeters.	Amount Dissolved per Square Centimeter. Grms.	Remarks.
			Total.	Per Cent.			
Quartz Crystal.	Herkimer, N Y..	0.5742	0.0002	0.035	1.5	0.000133	Not visibly etched.
Opal.....	....	0.4005	0.1140	28.46	1.5	0.076	Approximately same size.

With opal, the figure given as expressing the amount dissolved per square centimeter is necessarily lower than the truth, as the area of the exposed surface diminishes as the solvent action progresses. In the present case, the area at the end of the experiment is only about 80 per cent. of the area at the commencement, so that the loss per square centimeter will be somewhere between 0.095 and the figure given. The quartz crystal was without flaw, and was exposed on all faces. It did not show the slightest dimming of its brilliancy, and were it not for other experiments, it would be difficult to believe that the loss observed was not due to errors of experiment solely.

CRYSTALS OF QUARTZ.

Treated for 1 hour in Concentrated (54 per cent.) HF.

Locality.	Weight. Grams.	Amount Dissolved.		Area of Faces. Sq. Cm.	Amount Dissolved per Sq. Cm. Grms.	Remarks.
		Total.	Per Cent.			
Herkimer, N. Y.....	0.9733	0.0004	0.041	2.2	0.000182	Not visibly etched, perfect crystal, completely exposed.
White Plains, N. C...	0.6805	0.0016	0.235	.....	.....	Visibly etched, fractured surface also exposed.
White Plains, N. C...	6.5827	0.0024	0.036	7.2	0.000333	Visibly etched, acute rhombohedral faces exposed.
Hot Springs, Ark.....	22.0087	0.0050	0.023	11.9	0.000446	Visibly etched, prismatic faces exposed.

These figures show a quite decided, though small difference of susceptibility in the crystals from different localities. In the first "White Plains, N. C." specimen, the amount dissolved was relatively larger than in any of the others, but this is due to the exposure of the fractured surface, which is far more readily attacked than the natural faces, as the following experiments will show.

ACTION ON POLISHED SECTIONS OF QUARTZ CUT PERPENDICULARLY TO THE AXIS OF THE CRYSTAL.

Treated for 1 hour in 54 per cent. HF.

Total Area Exposed. Square Centimeters.	Weight. Grams.	Amount Dissolved.		Amount Dissolved per Square Cm. Grms.
		Total.	Per Cent.	
13.73	2.5242	0.0575	2.28	0.0042
15.24	2.2259	0.0778	3.49	0.0051
12.46	6.3890	0.0540	0.84	0.0043

In the last case, the natural faces of the crystal formed the sides of the section, and if we exclude them from our calculations, the area of the cut surfaces will be 8.46 sq. cm. and the amount dissolved per square centimetre of cut surface will be 0.0064. Here we see that the rate of attack is from 10 to 30 times faster than on the natural faces.

The etched surfaces of quartz crystals show a very peculiar variety of markings. Irregular and curved hair lines, having apparently no relation to the crystallographic form, are found in some places; the twinning structure is also developed, showing the complex nature of the crystal. On artificial surfaces of quartz the twinning structure is made very evident. In 1852–1855 F. Leydolt * made a series of experiments on quartz and agates with hydrofluoric acid, and says: "I am led to believe . . . . that agates . . . . . are composed of layers of different chemical constitution, or at least in a different state of aggregation. Quartz crystals preserve their brilliant surface and are not dissolved." He also says: † "The feldspar is dissolved, while the quartz remains quite unaltered," and again, "Wood opals and other quartzose stones show differences in constitution."

* Eine neue Methode die Achate, und andere quarzhaltige Mineralien naturgetreu darzustellen. Jahrb. d. K. K. geologischen Reichsanstalt, ii, Jahrgang 2, S. 124.

† Loc. cit., S. 126.

The action of hydrofluoric acid on different silicates has already been utilized as a means of purification * and for the proximate analysis of rocks,† but so far as I am aware, it has only been used to separate the insoluble or difficultly soluble minerals from the readily soluble ones with which they are associated. From the quantitative results presented in this paper, it will be readily seen how it may be applied to determine the nature of a mineral; to distinguish for instance between the different feldspars. It would also be possible to arrive quickly at the approximate composition of a rock of which the constituent minerals were known, such as a syenite or granite. When used in conjunction with Thoulet's solution, complex mixtures of minerals may be readily determined. I applied the acid to determine whether a specimen of cassiterite and quartz was only a mixture of the two minerals, or a silicate of tin, as was claimed for it by its European label. I obtained a residue of pure SnO_2, practically the whole amount present, which probably would not have been the case if it had been a compound.

Of course, the figures given in the present paper only apply to the circumstances under which the experiments were carried on; it is possible that with a different degree of comminution, or with a different strength of acid, the rate of attack might be different, so that each investigator would need to construct a table of solubilities suited to the circumstances under which he works.

Many analytical processes have been proposed, and used, either for the decomposition of silicates by hydrofluoric acid, or for the determination of fluorine by conversion into silicon fluoride. Now it is plain that in the latter case, quartz is about the worst material we can introduce to furnish the necessary silica; and in the former case, that we cannot depend on the complete decomposition of a silicate by simple treatment with hydrofluoric acid.

In conclusion, I desire to acknowledge my indebtedness to Dr. T. Sterry Hunt for many suggestions he has made, and information given, during the course of my experiments; to Dr. T. Egleston, for his kindness in furnishing me with most of the material for the investigation; and to Professor B. W. Frazier and Mr. Geo. F. Kunz for assistance in procuring special specimens.

* Treatment and Qualitative Composition of Zircon. Ed. Linnemann, Chem. News, p. 233, Vol. lii., 1885.

† Minéralogie Micrographique, F. Fouqué et Michel Lévy, Paris, 1879, p. 116; and T. Sterry Hunt, Mineral Physiology and Physiography, p. 214.

TREATMENT OF GOLD IN THE ARRASTRA.

BY T. EGLESTON, PH.D.

IN the year 1884 I had occasion to discuss the treatment of silver in the Patio process,* and the treatment of gold in the Arrastra in so far as native gold was found with the silver ores, and was, therefore, collected in the same process, but in a preliminary operation.† The treatment of certain kinds of gold ores by this apparatus is of great interest at the present time, when this very effective, but much misunderstood machine, is being extensively copied in principle in the new methods which are being devised for the treatment of gold ores.

Notwithstanding the extreme slowness with which it works, and the rapidity of the stamp-mill and the pan, it has not been entirely replaced by them, and can often be used where, from local circumstances, the nature of the ore, or the limited amount of capital at the disposal of the miner, neither the stamp nor the pan and settler could be used. The idea of modern amalgamation with the pan was undoubtedly taken from the arrastra, which the early settlers of California found in use among the Mexicans when they went to that State. It combines, although a very simple and often a very rude appliance, most of the best points of the stamp, the pan and the settler. But to the early miners the advantages of its simplicity of construction, its cheapness and its high yield, were as nothing compared with the necessity of making a large output in a short time, whatever the loss, and they thus modified it little by little, trying to keep its essential features and principles, until it disappeared so entirely that they lost sight even of the fact that it had ever been used. It has real advantages, however, which prevented its being absolutely relegated to the catalogue of historical metallurgical appliances. Its cheapness and simplicity of construction place it so easily within the means of those who have but little capital to invest, and, therefore, cannot erect a stamp-mill while prospecting, or even developing their claims. The economy with which it can be erected and worked, and the high yield which it gives of the

* Annals N. Y. Academy of Sciences, vol. iii., p. 1.

† Ibid., p. 12.

precious metals when it is properly managed, more than counterbalance the deficiency of output, especially when the claims are not rich, or where they are not certain to last for any great length of time. It is especially adapted to the class of free-milling gold ores which are generally found on the outcrops of veins or near the surface. Other classes of ores which are not free milling are not suited to it, or to any other process which does not require a much more expensive plant. Possibly the future may develop a leaching process for gold, as it has done for silver, which will be its equal, or perhaps its superior; but this is in the future, and for gold ores has not been realized, except where small quantities of gold ore are found in large quantities of silver. These facts have been so well recognized within the last few years that there are now many works, situated principally in the Western States and Territories, that are successfully working arrastras, which are giving a high yield. A very large number of such works have been erected since 1876. Some few antedate that time. The Accidental mine,* for example, in 1863 and 1864, treated in the arrastra 1000 tons of ore yielding $25 to $75 to the ton. The Sexton mine in the same year treated ore which averaged $37, and three tons of it gave $191 to the ton. Many of these works have been built as a makeshift to take advantage of some peculiar conditions which were known at the outset to be only of a temporary nature. Some few of them have been altered from abandoned pan-mills, but most of them have been constructed especially to treat the ores of small but productive mines. Occasionally they are built in districts where only small mines are found, as custom-mills, and without any mining property attached to them. Others have been built to treat the tails of old mills, which can often be done with large profit, or even poor tails, when free water power can be had. A number of such mills are at present working on Comstock tails. When steam is to be used the tails must be correspondingly rich enough to pay for the expense of the fuel used to get the power. As the life of such works is dependent on circumstances which are almost accidental, it is usually very short, for which reason they are rarely built by companies with much capital, but they serve very useful purposes at small mines and for working tails where the means at the disposal of the miner are very limited. They are em-

* Lock on Gold, p. 178.

ployed to a large extent in working free-milling gold ores. They are also used for treating silver ores containing gold which produces a doré bullion. They are not generally used on high-grade ores, as the pan is much quicker for such ores as these. Very little ore, averaging as low as ten dollars a ton, is treated in them. Generally the yield of the ore must be much higher. They do not differ essentially in construction from those which have already been described,* but they have been slightly modified from the Mexican original.

They are built with a circular pavement of rock 6 to 10 feet in diameter. This pavement is made of the hardest and toughest rock that can be found in the country. It should in preference be coarse rather than fine-grained, and should remain rough after long use, not becoming polished by the grinding action, as this would tend to allow the ore to slip around rather than to be acted upon. It should also have the power of rubbing the fine particles of metal bright, so that they will be quickly attacked by the mercury. The rock which is used for this purpose is generally granite or basalt, or some of the various kinds of compact quartz which are neither agates nor chalcedony, but intermediate between the two, which are so common in the west. When new this pavement is made at least 12 inches thick. The stones used must be as large as possible, they are jointed with great care and set in hydraulic cement, if it can be had, in order to prevent any leakage of mercury or amalgam, which will settle in the crevices of the stones, from which it may be picked out, but it should never go into the ground beneath. In the centre of this pavement a pivot is fixed for an upright post, which is supported overhead, and which carries a little above the level of the pavement from two to four arms. To these arms, stone drags, weighing generally from 200 to 1000 or even 2000 pounds, made of the same material as the pavement, are attached by ropes or chains. They are hung so as to be raised a little above the pavement in front, but they drag behind. The arms carry sometimes a single drag only at their ends; they occasionally have two, but rarely more. The number of drags in each arrastra varies from two to as many as twelve; when it is difficult to get stones of sufficient size, four is, however, the usual number. They are sometimes as light as 80 pounds; they will average,

* Annals N. Y. Academy of Sciences, vol. iii., p. 8.

however, at least 300 pounds when new; occasionally they are made as heavy as a ton. The arms to which they are attached are moved by horses, or mules, or by water power applied in the ordinary way, or by hurdy-gurdy wheels, or by steam. Their speed varies 4 to 18 turns per minute. When power is used it will average from 10 to 14 turns per minute. When the arms of a ten-foot arrastra make 14 turns the outer drag has a velocity of about 400 feet per minute. The average, however, will not be higher than from 200 to 300 feet per minute. The outside of the pavement is protected by a vertical wall made of flat stone ,or of plank driven into the ground, but made tight both on the inside and outside. It is from 18 to 30 inches above the pavement, according to the size of the arrastra. These planks or stones keep the pulp from spreading and fix the depth of the arrastra. In these sides there are either a series of round holes closed by wooden plugs like those in the common settler, or a gate on the side which is used to empty it.

The difficulty of getting the stone for the pavement, and of properly constructing it, has caused the invention of an iron arrastra,* which is really a double pan. It varies from 6 feet to 8 feet 6 inches in diameter. The central portion of this machine is a pan, the muller of which is used for grinding. On the outside of this there is a circular space 14 inches wide and 5 inches below the muller of the pan, in which a set of drags travel. It is fitted with a revolving amalgamated copper circle, which acts like the apron of gold-mills. It is run by power from below like the pan. Such an arrastra, 8 feet 6 inches in diameter, can treat from 7 to 10 tons of ore in twenty-four hours, the amount depending upon the fineness of the ore treated and its hardness. The whole machine weighs about 4½ tons, and requires five-horse power to move it.

The usual arrangement of the works is to have the arrastra a little below the level of, but directly in front of, the Chilian mill, rock breaker or stamps, and so near to it that there will have to be very little handling of the broken ore to reach the arrastra. The power is generally transmitted to the drags by a gear-wheel above and by a belt from the source of power. Where horses or mules are used they are generally hitched to the extension of the arms which carry the drags.

To treat the ore in the arrastra, it is first broken to the proper

* Invented by A. B. Paul, of San Francisco.

size. This is sometimes done by hand, but oftener by a Chilian mill, a crusher or by stamps. When stamps are used in connection with the arrastra, as they frequently are, either when a pan mill has been abandoned or its operation changed, so that certain classes of ore are treated in the pans and others in the arrastra, the mortars are set without screens and the ore crushed dry. The ore is fed as usual, but it is delivered by the blow of the stamp, just as it strikes it, so that it varies in size from dust to the size of a pigeon's egg. It is charged into the arrastra just as it comes from the stamp. A battery of five stamps will crush, in two hours, all the ore that a single arrastra can treat in 24 hours. Such a battery, therefore, will be capable of doing the work for 12 arrastras. It is always desirable to use either a crusher or a stamp, as it is more economical to break the ore in this way than to wear out the pavement of the arrastra in doing the same work. The crushed ore is shovelled or fed into the arrastra, and sufficient water added to make a thick pulp. A charge is generally from 600 to 1000 lbs. of dry ore. The arms are turned so that the drags act from two to four hours. The limit of time is fixed by testing the fineness of the pulp between the thumb and fore finger. The practice varies with regard to the addition of the chemicals, and also as to the chemicals used; in some mills they are added at the commencement, as soon as the drags are in movement; in others they are added at the same time with the mercury. The chemicals used with gold ores are a little potassium cyanide to "liven" the "quick," or some wood ashes or lye to neutralize the effect of any grease which may have got into the ore. Generally, no other chemicals are used. When the ores carry large amounts of silver, copper sulphate (bluestone) and salt, which are put in solid, are used in such quantities as the amalgamator thinks best, or the assay made by panning shows to be necessary. When the pulp has been ground long enough the mercury is added, the quantity depending upon the precious metal contents of the ore. It varies in amount, generally from 100 to 150 lbs. With high grade ores it is often from 200 to 250 lbs. Treating silver ores, or ores in which the silver is in excess, the amount of mercury added is large, often amounting to a pound of mercury or more for every ounce of silver. This makes a very liquid amalgam. But in treating gold ores, where the object is to produce rather a pasty amalgam, the amount is much less. The condition of the pulp

is judged of by sampling and panning it. Fire assays are not often made. When the assay shows that most of the precious metal has been caught by the mercury, the pulp is thinned with water and the speed of the drags reduced, in order to allow the amalgam to settle. After a time the arrastra is discharged, either by the holes in the side or by the gate. The time required for the operation, is from six to ten hours. The capacity of the simplest arrastra varies with the kind of treatment, and the completeness of the plant, from one to two tons a day. When the mill has rock breakers and stamps, so that it has but little grinding to do, the capacity depends upon the time necessary to complete the amalgamation. A twelve foot arrastra driven by power, with heavy drags, making 15 revolutions per minute, may treat two charges of two tons of ordinary ore in 24 hours, if very close work is not necessary, but this is the extreme limit of its capacity. When silver ores are treated the arrastra is often used only for grinding, the pulp is discharged into the pans and treated as in pan amalgamation, except that no grinding is done. When gold ores alone are treated the pulp is either washed into a settler, and the amalgam collected there, or the pulp is washed out of the arrastra and the amalgam collected in it. The table below* shows the amount of ore treated in 1880 by 22 arrastra works, with 53 arrastras, which were not all running continuously. The average per mill was 413.75, and the average for each arrastra 171.70 tons.

State or Territory.	Number of Works.	Number of Arrastras.	Tons Treated.
Arizona	4	9	195
California	4	13	3205
Colorado	2	6	284
Idaho	2	4	2022¼
Montana	3	5	2250
New Mexico	1	4	500
Oregon	6	12	645
Total	22	53	9101¼

When custom ore is treated, a clean-up is made for each run. It frequently happens that the amount of ore treated is very small, sometimes as low as half a ton when the ore contains from $500 to

* U. S. Census Rep., 1880, vol. 13, p. 283.

$600 to the ton or richer, so that the clean-ups have to be very frequently made. When the work is done on the ore owned by the works, it is generally made only once in two weeks. The amalgam is strained by hand in a canvas bag, and retorted in the usual way, the time occupied in the retorting, being usually seven hours. When custom ores are treated, the arrastra is sampled every half hour, to ascertain how the working is progressing, as well as to ascertain the real value of the ore. If it is worth while, the tails are afterwards treated in the pans. When the arrastras are used in silver mills, they are discharged, by the plugs in the side, into a wooden trough, which carries the pulp directly into the pans, and the treatment is the same as in a pan mill. The tails are worked in the pans exactly as ordinary tails are treated, the quantity of copper sulphate ranging from four to five pounds to the charge. The percentage of gold extracted by the first treatment generally reaches 90 per cent.; that of the silver, from 75 to 80 per cent. The arrastra is very often used in gold stamp mills to treat the pulp from the stamps. At the Iowa mill, in Idaho, and in a considerable number of works in California, the pulp from the stamp flows into a constantly working arrastra, and from there through a gate near the top of the side, on to amalgamated copper aprons and sluices. In such a continuous process, a flask of mercury is charged into the arrastra at the commencement of the run, and is removed as amalgam and free mercury at the clean-up.

The amount of labor required in this process is extremely small. One man per shift can easily take care of two arrastras. In some of them which work on tails, and are run by water power, the disposition of the mill is such, that the only labor required is in feeding and discharging them, so that it is much less than the work of one man. Very often the owner of the mill does all the work himself. When the arrastras are continuous in action, the amount of labor is still smaller, it being simply that which is required for repairs. The power which is required depends upon the size of the mill, but small arrastras are frequently worked by a single mule or horse. The table below gives the number of arrastras, the number and weight of the drags and the method of obtaining the power in thirty-two mills which work 211 arrastras.*

* Report of the U. S. Census for 1880, vol. 13, p. 281.

State or Territory.	Works.	Number of Arrastras.	Number of Drags.	Weight of Drags.	Motive Power.
				Pounds.	
Alabama	Houston & Pinson, Cleburne Co	1	6	100 to 300 each	8 horse-power engine; also runs battery.
Arizona	Gross & Smith, Mohave Co	2	2 each		4 horses.
	South Oro Belle, Yavapai Co	2	4 each	400 each	5 horse-power engine.
	Thunderbolt	4	4 each	175 each	20 horse-powerengine.
	Johnson	2	4 each	250 each	2 horses.
	Nash	3	6 each	200 each	1 horse for each arrastra.
California	Leper, Keys & Co., Calaveras Co	6	3 each	300 to 500 each	Overshot wheel, 28 ft. diam., 50 in. water.
	Potter, Calaveras Co	2	3 each	200 to 500 each	Overshot wheel, 20 ft. diam., 25 in. water.
	Champion, Calaveras Co	2	4 each	750 each	Overshot wheel, 40 ft. diam., 50 in. water.
	Fresno Enterprise, Fresno Co	3	4 each	800 to 1000 each.	
	Italian, Plumas Co	35	1 usually 4 each	500 to 2000 each.	Hurdy-gurdy wheels.
Colorado	George Bachelder, Boulder Co	2	2 each		Water-power.
	Rock Point, Ouray Co.	4	6 each	200 each	Turbine.
Idaho	Iowa, Boise Co	1	3 each	250–600 and 800	40 horse-power engine; runs battery also.
	Estes, Lemhi Co	1			Leffel turbine, 13¼ in. diam., 65 ft. fall.
	Nort.n's, Lemhi Co	2	4 each	1000–1200 each*	Overshot wheel. 15 ft. diam., 5 ft. face, 150 in. water.
	Scales & Wagner's, Owyhee Co	2	4 each	250 to 300 each	In winter, 30 horse-power engine; other 8 months, 20 feet overshot wheel, 4 feet face.
	Trask's, Owyhee Co	2	4 each	300 each	Overshot wheel, 24 ft. diam., 2 ft. face.
Montana	Black Tail, Deer Lodge Co	2	4 each	2000 to 3000	Water-power.
	Glen Egbert, Deer Lodge Co	1	4 each	500 each	Overshot wheel, 14 ft. diam., 2½ ft. face.
	Schafer, Lewis & Clarke Co	2	One 4; one 8	500 each	Overshot wheel, 33 ft. diameter.
	H. Siegchrist, Madison Co	2	4 each	800 each	Overshot wheel, 20 ft diam., using 60 in. water.
Nevada	E. R. Willis, Esmeralda Co	1	5 each	120 each	Undershot wheel.
	B. B. Chandler, Storey Co	1	4 each	200 to 500 each	Overshot wheel, 24 ft. diameter.
New Mexico	Skillicorn's, Grant Co	4	4 each	80 each	20 horse-powerengine.
North Carolina	Mann, Nash Co	10	4 each	200 to 400 each	40 horse-powerengine.
Oregon	McCord, Baker Co	2	4 each	300 to 500 each	Overshot wheel, 24 ft. diameter, 12 horse-power.
	Beagle, Grant Co	1	6 each	300 each	Hurdy-gurdy wheel, 10 horse-power.
	Sugar Pine, Josephine Co	2	4 each	600 each	Water wheel, 20 horse-power.
	Cooper & Lockwood, Yakima Co	3	6 each	200 each	Turbine, 20 ft. diam., 13 ft. fall, 9 horse-power.
	Shafer, Yakima Co	1	4 each	500 each	Horizontal hurdy-gurdy.
	Witer & Miller, Yakima Co	3	5 each		Hurdy-gurdy, 8 horse-power, and breast wheel, 20 horse-power.

* When new; used until worn to 250 or 300 pounds.

When water power can be used, small overshot or turbine wheels are used or a hurdy-gurdy if sufficient pressure can be had. When the mills are large and have rock breakers or stamps, they are usually placed in such a position that water power can be made available for certain seasons of the year. When, either from drought or cold, the water is not available, steam is used. The simplest form of arrastra, operated by mule power, can be built for from $100 to $150, which is the cheapest form in which it can be constructed. The cost varies from this point up to $1000 or even $1500, depending upon the size of the arrastra and the care taken in making the pavement and the weight of the drags. When flumes, pipes and ditches are required to bring the water, and water wheels and engines are used, and when pans are added for the treatment of the tails, the works may become very expensive. The complete cost* of 26 mills, having 92 arrastras, in 1880, was $137,590, or an average of $5292 for each works, or $1495 per arrastra, including all the rest of the plant. These mills, however, are of the best construction, and their cost is considerably above that of the ordinary arrastra mills. The following details refer to the working of Scales & Wagner's arrastra, Owyhee Co.,† Idaho, one of the best of all the arrastra mills. It produced in 1880 $205,331.75. The charge for custom ore in lots of 100 tons and over, is $15, for lots of 50 to 100 tons, $16, and a corresponding increase for smaller lots. The plant consists of a battery of 10 light stamps, 2 arrastras, 3 half-ton Wheeler pans, 2 settlers and a retort.

In the Summer, on 12 hours shift.

4 Men inside the mill at $4.00 per 12 hours shift,	$ 16.00
2 Laborers in the summer, on ten hours shift outwork, at $3.50,	$ 7.00
2 Engineers in winter, on 12 hours shift at $5.00,	$ 10.00
Number of days work,	330
Hours of labor to treat 1 ton of ore,	12.7
Cost of supplies per ton of ore treated,	$ 3.95
Tons of ore treated in 1880 (tails about 300 tons),	1,772.25
Lowest yield of ore,	$ 38.00
Highest yield of ore,	$ 600.00
Average,	$ 115.85
Yield of the tails,	$ 9.50

* U.S. Census, 1880, vol. 13, p. 282.

† Ibid., p. 284.

The following table gives the total amount of supplies consumed, and the amount per ton of ore treated:

Items.	TOTAL CONSUMPTION.		CONSUMPTION PER TON OF ORE TREATED.	
	Amount.	Cost.	Amount.	Cost.
Red fir.....cords..	575	4,168 75	0.32	2 35
Quicksilver.....pounds..	3,000	1,440 00	1.69	81
Salt..... do. ..	14,000	420 00	7.89	24
Bluestone..... do. ..	3,000	750 00	1.69	42
Lard oil.....gallons..	20	40 00	0.01	02
Chemicals and sundries.....	.....	200 00	.....	11
Total.....	.....	$7,018 75	.....	$3 95

THE GREAT TELESCOPES OF THE WORLD.*

BY J. K. REES.

LIKE all great inventions, the telescope may be considered the product of many minds. The inventor was one who worked out the proper combination of lenses, or mirrors with lenses. Long before the invention of the telescope, spectacle glasses or lenses had been made. In the 8th century, A.D., magnifying-spectacles for old people were commonly used. Seneca, who lived in the first century, tells us that, in his time, it was well-known that when writing was viewed through a globe full of water the letters looked larger and blacker. This appearance must have attracted the attention of many persons before the time of Seneca. The natural result of a such a discovery would be the invention of glasses to produce magnification. It is not strange, then, that we find the use of a simple magnifying-lens extending so far back that we are unable to fix the date for its discovery. But, down to the beginning of the 17th century, no one seems to have thought of com-

* Lecture delivered before the Engineering Society, School of Mines. The lecture was illustrated with lantern views.

bining two lenses together, one in front of the other, so as to render distant objects visible.

There appears to be some uncertainty as to the name of the original inventor of the telescope. Undoubtedly, Galileo was the first to publish to the world the manner of making the instrument, and, furthermore, he was probably an independent inventor; but it is well known that he was not the original inventor. In the Archives of the Hague, quoted by Arago, we read that a spectacle maker of Middleburg, named John Lippershey, addressed a petition to the States-General on October 2d, 1606, in which he asked leave to take out a patent, which should constitute him the only maker of an instrument capable of rendering distant objects visible, or which should confer upon him an annual pension, on the condition of not manufacturing the instrument for other nations. On the 4th October, 1608, the States-General appointed a deputy from each province to experiment on the new instrument, which was about one foot and a half in length. On the 6th of October, the commission declared the instrument to be useful to the nation, but demanded that it should be made for two eyes instead of for one. On the 9th of December, Lippershey announced that he had solved the problem. A favorable report was made on the 11th, and the binocular instrument was declared a success. "Saturnus tells us that an unknown man of genius called on Lippershey and ordered from him a number of convex and of concave lenses. At the time agreed upon the man returned and chose two lenses, one convex and the other concave, and, placing them one before his eye and the other at some distance from it, drew them backwards and forwards without giving any explanation of his manœuvres, paid the optician and left the place. As soon as he was gone Lippershey began to imitate the experiments of the stranger, and soon found that distant objects were brought apparently nearer when the lenses were placed in certain positions. He next fastened them to the ends of a tube, and lost no time in presenting the new instrument to Prince Maurice of Nassau."

According to another version, Lippershey's children were playing with the lenses, when one of them, happening to place a convex lens in front of a concave lens, was greatly surprised to see the vane of the clock-tower of the Middleburg Church apparently brought nearer. Lippershey's attention being called to the fact, he tried it, and, working out the idea, he invented the first telescope.

Metius, of Amsterdam, the discoverer of the ratio $\frac{355}{113}$ (the relation between the length of the circumference and the diameter of a circle) claimed to be the inventor. Jansen and Baptista Porta, and others disputed for the honor.

Inasmuch as the first telescopes were at once seen to be of great value in wars, it was attempted to keep the invention a secret. Galileo heard, through letters, that an instrument had been invented which rendered distant objects visible, but he obtained no account of the construction. He, however, on this hint, made a telescope after several trials. The highest magnifying power which Galileo used was nearly 30 diameters. He was the first to direct the telescope heavenward. He saw the spots on the Sun, the moons of Jupiter, the mountains in our Moon, the handles of Saturn, the phases of Venus and made other interesting discoveries.

Kepler suggested for the single biconcave lens near the eye, used by Galileo and others, a double convex lens, which gave a larger field. This combination is called the "Astronomical eye-piece." It inverts objects looked at.

It is foreign to my purpose to enter into the details of the construction of a telescope. You all know that the power of a telescope to magnify an object looked at depends upon the focal lengths of both object-glass and eye-piece. It is the ratio of the first to the second. If, then, our object-glass forms an image of the Moon at a distance of 100 inches from the centre of the glass, and we view that image with an eye-lens whose focal length is one-quarter of an inch, we obtain an image in the field of view, which is magnified 400 diameters. We can, therefore, increase our magnifying power either by making the focal length of the object-glass greater, or that of the eye-lens less, or by doing both. With a given object-glass we can, theoretically, make our magnifying power as great as we choose. If, in the case cited, we use an eye-lens with a focal length of say $\frac{1}{100}$th of an inch, we obtain a magnifying power of 100×100 or 10,000 diameters. "But in attempting to do this, a difficulty arises with which astronomers have always had to contend, and which has its origin in the imperfection of the image formed by the object-glass. No lens will bring all the rays of light to absolutely the same focus. When light passes through a prism the various colors are refracted unequally, red being refracted the least, and violet the most.

"It is the same when light is refracted by a lens, and the conse-

quence is that the red rays will be brought to the farthest focus and the violet rays to the nearest, while the intermediate colors will be scattered between. As all the light is not brought to the same focus, it is impossible to get any accurate image of a star or other object, at which the telescope is pointed. The eye sees only a confused mixture of images of various colors. When a sufficiently low magnifying power is used, the confusion will be slight, the edges of the object being indistinct and made up of colored fringes. When the magnifying power is increased the object will indeed look larger, but these confused fringes will look larger in the same proportion, so that the observer will see no more than before. This separation of light in a telescope is called chromatic aberration."

The early astronomers found no way to get rid of this difficulty. They discovered, however, that they could diminish the trouble by increasing the focal length of the telescope, and thus making the image larger. An object-glass, say, of 5 inches diameter, with focal length of 60 feet, would give no more confused image than the same object-glass with a focal length of 6 feet. The image formed by the first would be ten times as large as that formed by the second, so that a low power of eye-lens could be used, and hence the confused fringes produced the less disturbing effect with a given eye-lens, the greater the focal length of the object-glass. In this way Hughens, Cassini, Hevelius, Blanchini and other astronomers of the 17th century were able to obtain quite high magnifying powers. These astronomers made telescopes, of 100 to 150 feet focal length, and one man finished an object-glass whose focal length was 600 feet.

Cassini mounted the objective on the top of a long pole free to move, while the eye-piece was moved along near the ground until the object-glass and eye-lens were brought into line with the star to be observed. The tube of the telescope was dispensed with. Hevelius connected his object-glass and eye-piece by a long pole. Newton, in his treatise on Optics, declared that the improvement of the refracting telescope was "desperate," and he turned his attention to reflecting telescopes. But an English optician, named Dolland, about the middle of the 18th century, discovered a remedy. He found that by a combination of lenses of crown and of flint glass he could obtain an almost colorless image at the focus.

This, indeed, was a grand victory, and at once enabled the opticians to construct telescopes of less length.

They could now put more of the magnifying power in the eye-piece, and have a telescope of such a length as could be comfortably handled. Telescopes, made of such a combination of lenses as we have alluded to, are called "achromatic." As larger and more perfect achromatic telescopes were made, a new source of aberration was discovered, no practical method of correcting which is yet known. It arises from the fact that flint glass, as compared with crown, spreads out the blue end of the spectrum more than the red end. The consequence is that two lenses cannot be made so as to entirely get rid of the color. "In a small instrument the defect is hardly noticeable, the only drawback being that a bright star or other object is seen surrounded by a blue or violet ring formed by the indigo rays thrown out by the flint glass. If the eyepiece is pushed in so that the star is seen, not as a point, but as a small disc, the centre of this disc will be green or yellow while the border will be reddish purple. But, in the immense refractors of 2 feet aperture and upwards, this 'secondary aberration,' as it is called, constitutes the most serious optical defect." Some think that no art can cure this defect. Many methods have been tried, all without much practical value. The defect may be lessened in the same way that the astronomers of the 17th century lessened the effect of "chromatic aberration,"—viz., by lengthening the telescope. But the lenses of the 17th century were very small and light, compared with the large lenses now made. And it would be very difficult to mount rigidly a telescope 100 feet long, carrying one of the large modern lenses. Newcomb considers that, in the great refractors of recent times, the limit of optical power for such instruments has been very nearly attained.

Many of the telescopes of the older astronomers had object-glasses (of crown glass only) of from ½ an inch to 1 inch in diameter. Some were larger. After Dolland made his discovery the great difficulty experienced in obtaining discs of flint glass of the required degree of purity prevented the making of any large telescopes till the beginning of this century, when Guinand discovered a process of making large discs of glass free from air-bubbles and striæ, and of equal density throughout. Most of my audience understand that the object-glass of a refracting telescope

is the "vital part, the construction of which involves the greatest difficulty." Given the object glass and the rest of the telescope can be quite easily made. And in the making of the object-glass there are two perfectly distinct processes. First, there are the beautifully clear discs of crown and of flint glass to be obtained. This is the work of the glassmaker. And then these discs have to be ground and polished, so as to form perfect lenses which will give uncolored images and bring all the rays of light to one focus. This is the task of the optician. Both require extraordinary skill. Few men have it.

About the beginning of this century the "English Board of Longitude" offered a considerable reward for bringing the art of making flint glass for optical purposes to the requisite perfection; but it led to no important discoveries. The Academy of Sciences of Paris offered prizes in vain for this object, and it remained for a man, not distinguished by education nor a glassmaker by trade, M. Guinand, of Switzerland, to have the honor of arriving at the solution of the difficulties.

Pierre Louis Guinand was one of those geniuses who seem to have great intuition with immense perseverance. He is said to have had no knowledge of optics, yet when quite young he constructed a small telescope equal to the best of his time. He soon turned his attention to producing glass discs of the requisite purity for making large telescopes. "He obtained some flint glass from England, but this was not always perfectly pure. He melted it anew, but did not obtain satisfactory glass." He then erected an establishment in which he constructed with his own hands a very large furnace, and commenced the manufacture of glass; and finally succeeded in obtaining pieces large enough for telescopes. He afterwards discovered a method of softening pieces of perfectly pure glass for the purpose of giving them the form of a disc. In 1805 he was employed by Utzschneider to assist in making object-glasses at the celebrated optical establishment near Munich. Here he worked with Fraunhofer, but in a subordinate capacity. He had sold his secret with his service. After remaining here some nine years he returned home, drawing a pension from the Munich establishment so long as he did not reveal the secret or himself make object-glasses.

He could not long resist the temptation, and soon gave up the pension to undertake the manufacture of larger discs than any he

had previously made. In 1823 he produced a disc 18 inches in diameter. In 1824 he exhibited at the exposition in Paris a grand achromatic object-glass which excited the admiration of the king, and Guinand was invited to come to Paris to live. He, however, was in feeble health and old. He died in 1825 at the advanced age of nearly 80 years. Many think that Fraunhofer owed to Guinand much of his fame gained in making large object-glasses.

After the death of Guinand, his widow and one of his sons set up works in Switzerland. The other son was introduced to Bontemps of Paris. They succeeded in producing good flint glass in discs of from 12 to 14 inches in diameter. In 1848 Bontemps accepted an invitation to unite with Messrs. Chance Bros. & Co., of Birmingham, England, in their efforts to improve the quality of glass.

They have succeeded in producing some very large discs, notably the ones for the Newall telescope of 25 inches, and also the discs for the great Washington telescope of 26 inches diameter. The establishment of Guinand at Paris is now conducted by Feil, a grandson of P. L. Guinand. Feil made the discs for the great Austrian refractor, 27 inches in diameter. He also made the discs for the Princeton telescope, and furnished the discs for the great Russian telescope of 30 inches diameter, and those of 36 inches for the Lick Observatory of California.

The process of making these large discs seems to be well understood by Messrs. Chance and Fiel, so that the only difficulty in getting the large discs is the long delay. The Russian discs were received by the opticians (the Clarks), who do the polishing, in about two years after being ordered.

The flint disc for the Lick telescope was ready in about one year, and the crown was nearly ready in nine months after, but was broken in the handling. Newcomb thinks that the secret of the manufacture consists principally in the constant stirring of the molten glass during the process of making.

The reason why the glass-makers require so long a time to make the large discs may be understood from the following account:

"As optical glass is now made, the material is constantly stirred with an iron rod during all the time it is melting in the furnace, and after it has begun to cool, until it becomes so stiff that the stirring has to cease. It is then placed, pot and all, in the annealing furnace, where it is kept nearly at a melting heat for three weeks

or more, according to the size of the pot. When the furnace has cooled off the glass is taken out, and the pot is broken from around it, leaving only the central mass of glass. Having such a mass, there is no trouble in breaking it up into pieces of all desirable purity, and sufficiently large for moderate-sized telescopes. But when a great telescope of two-feet aperture or upward is to be constructed, very delicate and laborious operations have to be undertaken. The outside of the glass has first to be chipped off because it is filled with impurities from the material of the pot itself. But this is not all. Veins of unequal density are always found extending through the interior of the mass, no way of avoiding them having yet been discovered. They are supposed to arise from the materials of the pot and stirring-rod, which become mixed in with the glass in consequence of the intense heat to which all are subjected. These veins must, so far as possible, be ground or chipped out with the greatest care. The glass is then melted again, pressed into a flat disc, and once more put into the annealing oven. In fact, the operation of annealing must be repeated every time the glass is melted." Annealing consumes two months each time for the large discs. "When cooled it is again examined for veins, of which great numbers are sure to be found. The problem now is to remove these by cutting and grinding without either breaking the glass in two or cutting a hole through it. If the parts of the glass are once separated they can never be joined without producing a bad scar at the point of junction. So long, however, as the surface is unbroken, the interior parts of the glass can be changed in form to any extent. Having ground out the veins as far as possible, the glass is to be again melted and moulded into proper shape. In this mould great care must be taken to have no folding of the surface. Imagining the latter to be a sort of skin enclosing the melted glass inside, it must be raised up wherever the glass is thinnest, and the latter allowed to slowly run together beneath it.

"If the disc is of flint, all the veins must be ground out on the first or second trial, because after two or three mouldings the glass will lose its transparency. A crown disc may, however, be melted a number of times without serious injury. In many cases—perhaps the majority—the artisan finds that after all his months of labor he can not perfectly clear his glass of the noxious veins, and he has to break it up into smaller pieces. When he finally suc-

ceeds, the disc has the form of a thin grindstone two feet or upward in diameter, according to the size of the telescope to be made, and from two to three inches in thickness. The glass is then ready for the optician.

"The first process to be performed by the optician is to grind the glass into the shape of a lens with perfectly spherical surfaces. The convex surface must be ground in a saucer-shaped tool of corresponding form. It is impossible to make a tool perfectly spherical in the first place, but success may be secured on the geometrical principle that two surfaces cannot fit each other in all positions unless both are perfectly spherical. The tool of the optician is a very simple affair, being nothing more than a plate of iron somewhat larger, perhaps a fourth, than the lens to be ground to the corresponding curvature. In order to insure its changing to fit the glass, it is covered on the interior with a coating of pitch from an eighth to a quarter of an inch thick. This material is admirably adapted to the purpose because it gives way certainly, though very slowly, to the pressure of the glass. In order that it may have room to change its form, grooves are cut through it in both directions, so as to leave it in the form of squares, like those on a chess-board.

"It is then sprinkled over with rouge, moistened with water, and gently warmed. The roughly ground lens is then placed upon it, and moved from side to side. The direction of the motion is slightly changed with every stroke, so that after a dozen or so of strokes the lines of motion will lie in every direction on the tool. This change of direction is most readily and easily effected by the operator slowly walking around as he polishes, at the same time the lens is to be slowly turned around either in the opposite direction or more rapidly yet in the same direction, so that the strokes of the polisher shall cross the lens in all directions. This double motion insures every part of the lens coming into contact with every part of the polisher, and moving over it in every direction. Then whatever parts either of the lens or of the polisher may be too high to form a spherical surface will be gradually worn down, thus securing the perfect sphericity of both.

"When the polishing is done by machinery, which is the custom in Europe, with large lenses, the polisher is slid back and forth over the lens by means of a crank attached to a revolving wheel. The polisher is at the same time slowly revolved around a pivot at

its centre, which pivot the crank works into, and the glass below it is slowly turned in the opposite direction. Thus the same effect is produced as in the other system. Those who practice this method claim that by thus using machinery the conditions of a uniform polish for every part of the surface can be more perfectly fulfilled than by a hand motion. The results, however, do not support this view. No European optician will claim to do better work than the American firm of Alvan Clark & Sons in producing uniformly good object-glasses, and this firm always does the work by hand, moving the glass over the polisher and not the polisher over the glass."

Little imperfections are sure to exist after the first polishing. It is in the nice correction of these that the great skill of the optician is shown and much time is consumed.

The American firm of Alvan Clark & Sons enjoys the reputation of being the best opticians in the world for polishing large lenses.

When the Russian Government decided to construct a telescope that would surpass in size the great Washington telescope of 26 inches diameter of object-glass, Otto Struve, the director of the Imperial Observatory, was commissioned to make an examination of the optical workshops of the world to discover where the best object-glass makers could be found. After he had made a thorough examination in Europe and in this country, he gave the contract to the firm of Alvan Clark & Sons. This great object-glass 30 inches in diameter is now completed. When the Russian glass was contracted for, the trustees of the Lick Observatory in California ordered an object-glass of 36 inches aperture—so that we still have in the United States the largest refracting telescope in the world.

I have dwelt upon the object-glass of a great refracting telescope because of its vital importance. We will have some explanations to make in regard to mountings, etc., when at the close of the lecture we throw on the screen several pictures to illustrate our subject.

As we have previously stated, Isaac Newton, in the latter part of the 17th century, regarded that there was no remedy for the defects in the refracting telescopes as then made, and he turned his attention to reflecting telescopes. Now it is well known that when parallel rays of light fall on a concave mirror they will all be reflected

back to a focus, there forming an image of the object from which the rays emanate. The form of this concave mirror must be such that a section of it cut by a plane parallel to the length of the telescope will be a parabola. The image formed will be made up of *all* the rays—there will be no such thing as chromatic aberration. Thus if a mirror could be made and would continue of the true parabolic shape, the great and desperate difficulty in the way of improving the telescopes might be removed.

In the time of Newton, the reflecting telescopes, however, did not excel the long refracting telescopes. Even after Dolland's discovery, the great difficulty met with in obtaining pure glass, made the earlier short achromatic telescopes not much better than the long instruments. But in the latter part of the 18th century a genius arose who solved the problem of the construction of large mirrors. History tells us that "William Herschel, in 1766, was a church organist and teacher of music, of high repute in Bath. He spent what little leisure he had in the study of Mathematics, Astronomy and Optics. By accident a Gregorian reflector two feet long, fell into his hands, and, turning it to the heavens, he was so enraptured with the views presented to him, that he sent to London to see if he could not purchase one of greater power. The price named was far above his means. He resolved, then, to make one for himself. After many experiments with metallic alloys, to learn which would reflect most light, and many efforts to find the best way of polishing his mirror, and giving it a parabolic form, he produced a five foot long (Newtonian) reflector, which revealed to him a number of interesting celestial phenomena, though, of course, nothing that was not already known."

He determined, then, to make the largest telescope that could be made, and after many failures, he produced a telescope having a mirror two feet in diameter and 20 feet long. At this time, 1781, he discovered the planet Uranus. His fame coming to the ears of the king, George III., that monarch gave him a pension of £220, that he might devote his life to the study of the heavens. He now accomplished his greatest work, by making a reflector four feet in diameter and forty feet long. With this he discovered two new moons of Saturn.

It was not until 1842 that another great step was taken in the direction of increasing the power of the reflecting telescopes. Then the Earl of Rosse, of Parsonstown, Ireland, constructed

(using steam machinery for grinding and polishing) a great mirror, six feet in diameter, the tube being fifty-four feet in length. The telescope has not done as much work as was expected, owing to the bad climate of the region where it is placed. It has been said that there are only a few hours in the year when the telescope can be used with its greatest efficiency.

Since 1842 a considerable number of large reflecting telescopes have been made. But as a general rule (though silvered glass mirrors have been substituted for those of metallic alloy), the reflectors have not given as much satisfaction as was to be expected. The large ones are more difficult to handle; the mirror tarnishes readily, and has to be frequently resilvered, and the alternations of heat and cold and of flexure produce a distortion of the curve which makes the mirror focus badly. These difficulties are so troublesome that refractors are usually preferred.

* * * * *

I append a table giving the locations, character and aperture of the great telescopes of the world.

SIZE OF PRINCIPAL TELESCOPES IN THE WORLD.

Refractors.

Owner and Location.	Constructed by.	Aperture.	Remarks.
Lick Observatory, Cal.,	A. Clark & Sons,	36 in.	
Pulkova, Russia,	A. Clark & Sons,	30 "	Finished in May, 1883.
Yale College,	A. Clark & Sons,	28 "	Constructing.
Littrow, Vienna,	Grubb,	27 "	
University of Virginia,	A. Clark & Sons,	26 "	
Washington Naval Observatory,	A. Clark & Sons,	26 "	
Gateshead, England,	Cooke,	25 "	
Princeton, N. J.,	A. Clark & Sons,	23 "	
Buckingham, London, England,	Buckingham,	21 "	
University of Chicago,	A. Clark & Sons,	18.5 "	
Strasbourg,	Merz,	18 "	
Private Observatory, Buffalo,	Fitz,	18 "	
Warner Observatory, Rochester,	Clark & Sons,	16 "	
Washburne Observatory, Madison, Wis.,	Clark & Sons,	15.50"	
Harvard College,	Merz,	14.95"	
Pulkova, Russia,	Merz,	14.93"	
Lord Lindsay, Dun Echt,	Grubb,	15 "	
Royal Society near London,	Grubb,	15 "	
Downsede College, Bath,		14.5 "	Destroyed by fire in 1867.

Owner and Location.	Constructed by.	Aperture.	Remarks.
Markree Castle,		14 in.	
Oom, Lisbon,	Merz,	14 Fr. in.	
C. H. F. Peters, Clinton,	Spencer,	13.5 in.	
Boss, Albany,	Fitz,	13 "	
Columbia College Observatory,	Rutherfurd & Fitz,	13 "	Photographic lens attachable. Presented to Columbia College by Mr. Rutherfurd in Dec. 1883.
Allegheny Observatory, Pa.,	Fitz,	13 "	
Ann Arbor, Mich.,	Fitz,	12.5 "	
Christie, Greenwich,	Merz & Simms,	12.5 "	
Vassar College,	Fitz, rewrk'd by Clark,	12.5 "	
Pritchard, Oxford,	Grubb,	12.25 "	
Glasgow, U. S.,	A. Clark & Sons,	12.25 "	
Paris,	Secretan & Eichens,	12 Fr. in.	
Littrow, Vienna,	A. Clark & Sons,	12 in.	
Adams, Cambridge,	Cauchoix,	12 "	
White, Brooklyn, N. Y.,	Fitz,	12 "	
Ball, Dublin,	Cauchoix,	12 " (?)	
H. Draper, nr. New York,	A. Clark & Sons,	11 "	
Main, Oxford,	Cauchoix,	12 " (?)	
Pritchard, Oxford,	Grubb,	12 "	
Cincinnati,	Merz,	11.5 "	
Bothkamp, Germany,	Schroeder,	11.7 "	
Cordova, S. A.,	Fitz,	11.2 "	
Munich, Germany,	Merz,	11 "	
Copenhagen, Denmark,	Merz,	11 "	
Middletown, Conn.,	Clark & Sons,	11 "	
And many others.			

Reflectors.

Owner and Location.	Constructed by.	Aperture.	Remarks.
Lord Rosse, Birr Castle,	Rosse,	6 feet.	
William Herschel, Slough,	W. Herschel,	4 "	Out of use.
Lassell, Liverpool, etc.,	Lassell,	4 "	Since destroyed.
Ellery, Melbourne,	Grubb,	4 "	
Paris,	Martin, Eichens,	4 "	Silvered glass.
Lord Rosse, Birr Castle,	Rosse,	36 in.	Silvered glass.
Common, England,		36 "	
Tisserand, Toulouse,	Foucault,	32.4 "	
Stephan, Marseilles,	Foucault, Eichens,	31.5 "	
H. Draper, nr. N. Y..	H. Draper,	28 "	Silvered glass.
Lassell, Maidenhead,	Lassell,	24 "	Metal.
W. & H. Herschel, Slough and C. G. H.,	W. & J. Herschel,	18 "	Several mirrors.

Owner and Location.	Constructed by.	Aperture.	Remarks
H. Draper, nr. N. Y.,	H. Draper,	15 in.	
MacLean, Tunbridge Wells,	With & Browning,	15 "	
Pritchard, Oxford,	De La Rue,	13 "	
Worthington & Baxendell, Manchester,	With & Browning, (?)	13 "	
And many others.			

NOTE.—The object-glass of the Lick equatorial is to cost,	$52,000 00
Photographic lens of crown glass, ...	13,000 00
Mounting of telescope, ...	42,000 00
Dome and machinery, ...	56,800 00
Total, ...	$163,800 00

Mr. A. Swazey, of Cleveland, furnishes the following data in regard to the great Lick telescope:

Focal length 56 feet.

Length of polar axis 12 feet.

Diameter of polar axis 12 inches, with a cylindrical hole 5 inches in diameter.

Declination axis: length, 12 feet; diameter, 10 inches, with 5-inch hole.

Largest circles 3 feet in diameter.

The tube of steel will weigh about 3 tons. The tube and all the movable parts (polar axis, etc.) will weigh 12 tons. The "head" will weigh 3 tons, and the pier 10 tons, making a total of 25 tons.

The lenses with their cell weigh about 700 pounds.

It has been stated that the photographic lens cracked in three pieces while the Clarks were polishing it.

ANALYSES OF FRAKLINITE AND SOME ASSOCIATED MINERALS.

BY GEORGE C. STONE.

THE following analyses were made to see if there was enough difference in the specific gravity of the different minerals to admit of their separation by mechanical means, and to see if, when separated, they would be sufficiently increased in value to pay for the operation. The specimens were all picked from ore from the two

mines of the New Jersey Zinc and Iron Company, in Sussex County, N. J. The ore from the Taylor Mine at Franklin Furnace is mainly franklinite, willemite, and zincite, with small quantities of several other minerals. The ore from the Sterling Hill Mine near Ogdensburg is mostly franklinite and calcite with very variable quantities of zincite.

The ore from both mines has changed considerably in character since the mines have been worked to greater depths. Dana says, the ore of the Taylor Mine is franklinite, zincite and garnet, and of the Sterling franklinite and willemite.

The analyses were all made of material picked as clean as possible from hand specimens of ore.

I. *Zincite.*—In rounded and angular grains from the Sterling Mine. Color, dark red; powder, orange. Specific gravity, 5.531. Composition:

Fe_2O_3,	0.44
MnO,	6.50
ZnO,	93.28
	100.22

II. *Zincite.*—A rounded mass made up of plates about one-tenth of an inch thick. Color, dark red; powder, orange. Specific gravity of lump, 5.507. Composition:

Fe_2O_3,	0.36
MnO,	5.54
ZnO,	94.30
	100.20

Franklinite.—I find two distinct varieties of franklinite, differing both physically and chemically; both correspond to the general formula, RO,R_2O_3. One kind has rather dull lustre; gives brown or reddish-brown powder; dissolves with some difficulty in hydrochloric acid without any evolution of chlorine. In this variety all the manganese is as protoxide. The second variety has more lustre; gives a black powder; dissolves very readily in hydrochloric acid with evolution of chlorine. This second variety contains much less iron and more manganese, partly as protoxide and partly as sesquioxide. Dana gives the specific gravity as 5.069 to 5.091. I find it rather higher—5.074 to 5.215.

III. *Franklinite.*—From Sterling Hill. Rounded crystals so distorted that the original form cannot be distinguished. Part of the same specimen as I. Color, dull black; powder, dark reddish. Dissolves with difficulty. Specific gravity, 5.215. Composition:

Fe_2O_3,	67.38
MnO,	16.38
ZnO,	16.28
	100.04

Formula.—$[\frac{8}{11}$ MnO, $\frac{9}{11}$ ZnO$]$ Fe_2O_3.

IV. *Franklinite.*—Taylor Mine. Granular with willemite. Color, dull black; powder, black. Dissolves very readily. Specific gravity, 5.187. Composition:

Fe_2O_3,	60.52
Mn_2O_3,	6.79
MnO,	12.81
ZnO,	19.44
	99.56

Formula.—$[\frac{3}{7}$ MnO, $\frac{4}{7}$ ZnO$]$ $[\frac{6}{7}$ Fe_2O_3, $\frac{1}{7}$ $Mn_2O_3]$.

V. *Franklinite.*—Massive, lustrous black, with a bluish tarnish. Tougher and harder to break than any of the other specimens tested. Powder, black; dissolves readily. Associated with zincite, calcite and willemite. Specific gravity, 5.136. Composition:

Fe_2O_3,	56.57
Mn_2O_3,	10.52
MnO,	16.37
ZnO,	15.91
	99.37

Formula.—$[\frac{9}{17}$ MnO, $\frac{8}{17}$ ZnO$]$ $[\frac{14}{17}$ Fe_2O_3, $\frac{3}{17}$ $Mn_2O_3]$.

VI. *Franklinite.*—Sterling Mine. Crystals with zincite in calcite; same specimen as II. Color, dull black; powder, dark red. Dissolves with difficulty. Specific gravity of crystals, 5.074. Composition:

Fe_2O_3,	66.34
MnO,	12.31
ZnO,	20.26
	98.91

Formula.—$[\frac{2}{3}$ MnO, $\frac{1}{3}$ ZnO$]$ Fe_2O_3.

VII. *Willemite.*—Taylor Mine. Dull lustre, nearly white; powder, white. Massive. Specific gravity, 4.188. Composition:

SiO_2,	27.20
FeO,	0.23
MnO,	6.97
ZnO,	65.82
	100.22

Formula.—$[\frac{1}{8}\ MnO, \frac{7}{8}\ ZnO]_2\ SiO_2$.

VIII. *Willemite.*—Taylor Mine. Grains with franklinite; same specimen as IV. Color, pale green; powder, white. Vitreous lustre. Specific gravity, 4 188. Composition:

SiO_2,	26.92
FeO,	0.51
MnO,	7.78
ZnO,	65.04
	100.25

Formula.—$[\frac{2}{17}\ MnO, \frac{15}{17}\ ZnO]_2\ SiO_2$.

IX. *Willemite.*—Taylor Mine. Massive, dull lustre. Color, mixed red and white; powder white. Very tough and hard. Specific gravity, 4.182. Composition:

SiO_2,	28.30
FeO,	0.31
MnO,	4.92
ZnO,	66.68
	100.21

Formula.—$[\frac{1}{12}\ MnO, \frac{11}{12}\ ZnO]_2\ SiO_2$.

X. *Willemite.*—Taylor Mine. Massive, vitreous lustre. Color, greenish-yellow, shading to clear yellow; powder, white. Subtranslucent. Specific gravity, 4.165. Composition:

SiO_2,	27.48
FeO,	0.49
MnO,	8.33
ZnO,	63.88
	100.18

Formula.—$[\frac{1}{8}\ MnO, \frac{7}{8}\ ZnO]_2\ SiO_2$.

XI. *Willemite.*—Taylor Mine with franklinite and calcite. Massive, dull lustre. Color, dark red; powder, pink. Specific gravity, 4.132. Composition:

SiO_2,	27.14
FeO,	1.24
MnO,	6.30
ZnO,	64.38
	99.06

Formula.—$[\frac{1}{10}\ MnO, \frac{9}{10}\ ZnO]_2\ SiO_2$.

XII. *Tephroite.*—Taylor Mine. Massive with franklinite and calcite. Opaque, dull lustre, dark red brown; powder, pink. Easily cleavable. Gelatinizes. Specific gravity, 3.913. Composition:

SiO_2,	30.63
FeO,	3.33
MnO,	49.80
MgO,	10.16
ZnO,	5 74
	99.66

Formula.—$[\frac{14}{21}\ MnO, \frac{5}{21}\ MgO, \frac{1}{21}\ FeO, \frac{1}{1}\ ZnO]_2\ SiO_2$.

Dana, p. 260, says that the oxide of zinc found in analyses of this mineral is due to a thin scale of zincite often found on the cleavage surfaces. It may have been so in this case, though I could see none with a hand lens, and from the comparatively large quantity I found, I think it should have been visible if present merely as a mixture.

OUR GRANDEST MOUNTAIN AND DEEPEST FOREST.

BY BAILEY WILLIS.

BETWEEN the Cascade range on the east and the Olympics on the west the landlocked waters of Puget Sound sparkle and dance merrily over the grave of a buried valley.

Seen from their heights the bright surface is still framed in sombre forests of tall evergreens, among whose straight trunks the axe blows are echoing, but a hundred years hence those growing on the high spurs will look down on fertile fields, where the panther and bear prowl to-day; and they will whisper in the evening breezes, that things are wondrous changed since they were young, threescore decades ago. But what are tens or hundreds of years to those youthful mountains, whose volcanic birth-throes lasted many centuries, and whose infancy of fire was followed by

an arctic winter, that still clings with icy hand to the mightiest of them all, Mount Tacoma.

Old as these mountains are, if judged by generations of men, they are for mountains still young, scarcely on the down-hill side of life, and there is a record which goes back to the time when the Cascades were not; but in their place was a great marshy plain, that stretched hundreds of miles along the Pacific coast and far inland toward the Rocky mountains. The record is written on beds of sandstone and coal, piled up by streams and plants in alternating layers a small fraction of an inch each year, till the superimposed strata were 14,000 feet thick; and during this deposition the great plain sank under its load into the bosom of the earth, sometimes quickly—say six inches in a century—sometimes imperceptibly, but never so that the ocean could rush over the swampy shore-line, constantly built up by the rivers and trees. In time there came a change, the strata were compressed laterally by tremendous force, folded like sheets of paper, lifted many thousand feet to form the Cascade range and left upturned, a prey to the gnawing tooth of time.

During the long ages of this uplift, the pressure and the heat, developed by it, altered peat beds to lignite and in some places to bituminous coal. The force manifested itself also in those volcanic eruptions, which have lasted until within the memory of Indian tradition, and may again illumine their gigantic monuments with their own fire-light. While volcanoes thus built up their cones, ten to fourteen thousand feet high, air and water hollowed out the basin of Puget Sound and a great river flowed northward, past the heights on which the wharves of Seattle and Port Townsend are building. The mountain top, which once looked down the old valley to green plains, where the waves now play in the Strait of Fuca, is to-day held at high prices per foot along the water front of an ambitious little city.

One of the branches of this submerged valley underlies Commencement Bay and the Puyallup river, and it is to the headwaters of the latter, that I would invite attention; for there is a narrow strip of those crumpled sandstones and coal-beds of the old plain, valuable in proportion to the condensed character of the coal, and beyond the coal-fields are the cañons and glaciers of Mt. Tacoma, whose triple summit happens just now to be 14,300 feet above the sea.

Above its hop-growing delta, the Puyallup receives Carbon river from the right, and the railroad to the coal mines, following up the latter a few miles, turns up Flett's creek to Wilkeson. Here you are already in the foot-hills, 31 miles from New Tacoma, where ten years ago, old David Flett first found the coal in yonder little point of rocks at the edge of the brook. With the usual directness of western enterprise, the railroad was built to the point of discovery, which fortunately now proves to be also the best point of development, and explorations were pushed several miles up Flett's creek. The coal mines were opened, badly managed, and shut down; and the little town, that had begun to spring up, was almost deserted. The useless shaft filled with water; the luxuriant undergrowth obliterated the forest paths, and the four families remaining had nothing to do but turn out once a day to welcome the coal train, which condescended to stop on its way to the more fortunate mining town of Carbonado.

It was a dreary September day when I first went to Wilkeson to explore for coal: the winter rain was heralded in the damp atmosphere and gray sky. All about grew the mighty primeval forest, reaching without a break to the snow line on Mt. Tacoma. Perhaps nowhere else in the United States does the plant-world predominate as it does in our most western mountains; game of all kinds is very scarce; vegetation is rankly luxuriant. On the uneven surface of soil, mould and fallen trees is spread a deep spongy carpet of golden brown moss, netted with glossy vines and relieved by tall ferns, whose fronds brush the shoulder. The red and blue huckleberry and the salmon-berry bushes lock arms above your head with the graceful boughs of the vine-maple and the darker green of young hemlocks. Those deeply cut delicate leaves that quiver in yonder beam of sunlight are maple; their brightness is in pleasant contrast with the uniform shadow beneath the dense canopy of fir boughs, which hangs so high it never oppresses one, though the sky is seldom visible. The fir trees rise a hundred feet and more before their branches meet across the narrow colonnades, and the long vistas between their brown trunks are like vast cathedral aisles. It is a silent forest; there are no chirping insects, no pattering raindrops, the plant world reaches upward toward the sun in absolute stillness, unstirred by fitful breezes, save when a gale roars through the distant tree-tops and the tall shafts bend moaning to its might.

Beneath this noiseless busy world lay the coal-field, hidden from sight except in the gorge of Flett's creek and in the cañon of Carbon river; and what I saw in the upturned beds of their rocky walls warned me, that good coal was not by any means to be found under every square mile of surface. As I noted the absence of all clews to the geologic structure my heart sank, but I had found a companion equal to the occasion. "Billy," probably so-called because his name was not William, was a short, broad-shouldered, deep-chested Irishman, agile as a cat and wiry as his little black mustache. In the great wind-falls, where the trees lie tangled like jack-straws, he would run along some sloping trunk, balance on its swaying end to give me an encouraging smile and leap across spaces his four-handed ancestors would have shrunk from. He had washed gold in California and spent it royally in 'Frisco; he had worked in the coal mines for a "grub stake" and sunk it in the quartz mines of Cassiar, but he had come to his senses while still a young man, and settled down to earn a steady living. Handy with axe, pick or frying pan, energetic, plucky and honest, "Billy" was a jewel. He looked upon me from the first as his particular charge. I fell once from a rotten tree and plunging headlong I caught myself among some roots on the brink of a cliff; my first glance was at the torrent two hundred feet below me, my second at "Billy," who stood crouched on the steep bank ready to spring; had I rolled a foot further, had he jumped to catch me and our fate would have been an unsolved mystery still. From him I learned to roll a "pack," as we called the load of food, clothing and blankets, that every man, who ventures more than a day from camp, must carry in those pathless wilds, where no horse can follow. We had no use for knapsacks, hung high on the shoulders, nor were we stiff-necked enough to carry a hundred pounds on a strap over the forehead, as Indian packers do; but we put everything in our blankets in a roll that reached from the shoulders below the hips. A woodsman should thus take sixty-five to eighty pounds, travel ten to twelve hours, over mountains, through wind-falls or jungles, and be ready at night to make camp, chop wood, bake bread, sing a song or spin a yarn, blow it wet or dry, cold or warm. Such a woodsman was "Billy" and another whom we called "Sam," a tall spare Yankee sailor, a man of iron nerve, but gentle heart, who never knew fear, but could be tender as a woman. Naturally quiet and under orders to say nothing of

his discoveries, Sam's work was enveloped in mystery for the rest of the crew. To-night he asked the cook for an early breakfast and chose a companion; to-morrow they were gone. When after many days they returned, the comrade knew but vaguely where he had been, as a sailor might guess his course on the ocean, and he always had some tale to tell of Sam's daring or endurance. When we laid him at rest in the little church-yard at Puyallup, that company of forty men, at the suggestion of one of their number, raised a good subscription to put a stone at his grave, and all the camp was quieter for days. Yet many of them had known him but a few weeks; they were men of rough looks, coarse ways and adventurous lives; lumbermen from Maine, prospectors from Arizona and Mexico, frontiersmen from Montana and Oregon, miners from Australia, mountaineers from the Tyrol and the Italian Alps, Prussians and Norwegians; but each and all had learned to be independent and self-reliant, to value a good comrade and despise a shirk, and they gave Sam the quick regard of men for manliness.

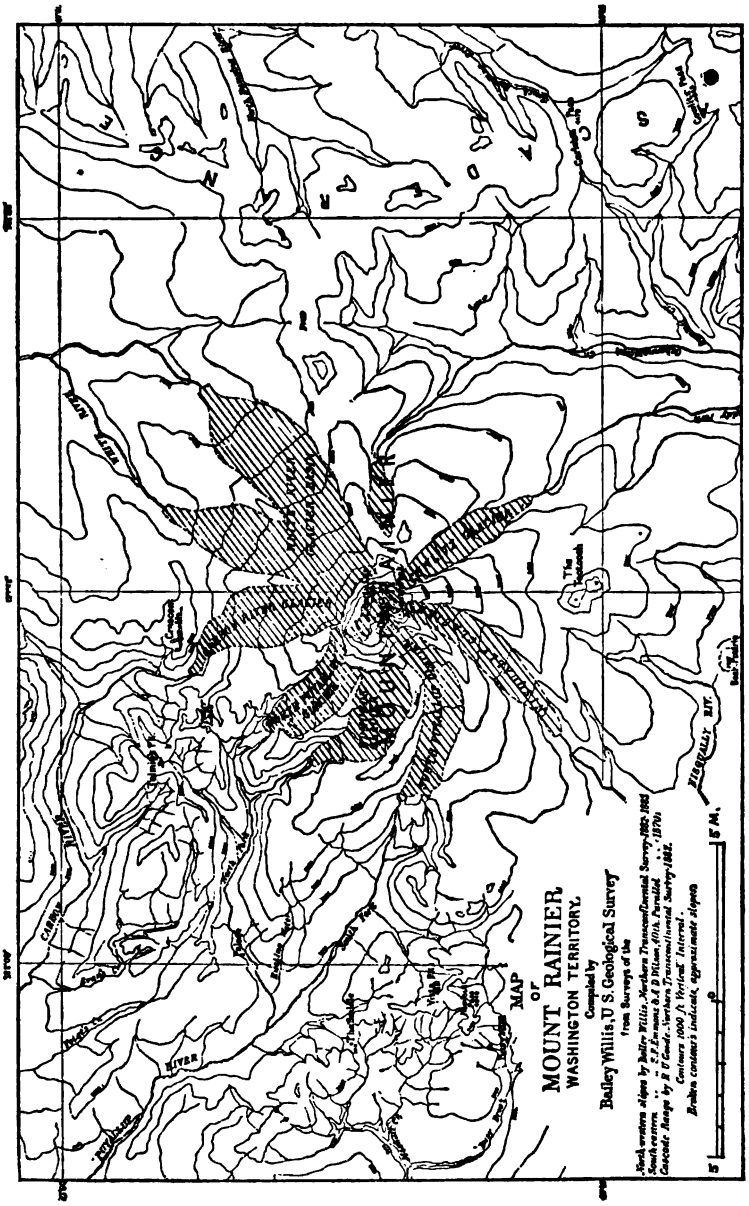
A year after my first arrival in Wilkeson, the coal problem was approaching a partial solution, and I had an opportunity to turn my steps towards Mt. Tacoma, whose snowy heights had been a source of constant temptation to excursions far outside my main purpose. Sam's tall figure, in blue overalls and brown shirt, bending slightly under his pack, still strides in memory ahead of me over the gray shingle of the bed of Carbon River, while my younger companion walks by my side. We were the first, so far as we knew, to strike for the source of the river, though we had probably been preceded many years by hunters for gold or furs, and our trip had all the charm of original exploration. We carried five days' provision, and were determined that the spirits of Indian chiefs, who haunt Tacoma's slopes, should not daunt us, though they whistle never so shrilly, as the story goes, among the stunted pines. The upper valley of Carbon River is but a stretch of sand and boulders, two hundred yards wide, through which the milky current rushes from bank to bank; on either side, bold mountains rise, often in precipices, three to four thousand feet. We had to choose between toiling through the underbrush or wading the icy stream waist deep, as often as it crossed our direct path up the valley. We took the latter course, and where the current was strongest joined hands, the last steadying the first and *vice versa*,

when in the deepest channel. Many times our feet slipped or we stepped suddenly into holes of uncomfortable depth. Toward nightfall we approached a bend in the river, that we had had in view for several hours. There was a race to reach it first, and then a shout from all three, as we looked into the glowing crater of a volcano, five thousand feet above us. The near wall was broken down, and past its black buttresses we saw the far cliffs, a thousand feet high, all aglow with ruddy light; from an active crater? The illusion faded with the sunset as the mountain turned to cold gray and white of rock and snow. We were soon enjoying pleasures greater than epicure ever knew—hot tea and hot crisp bacon right out of the frying-pan, eaten beside a roaring camp fire. We had earned our rest well that day, and we made the most of it, casting a look at our clothing now and then, drying on some sticks near by. Our comfort had beguiled us into inattention, when Sam sprang up, crying "Just in time;" to save one leg and the belt of his overalls from the flames. Sleeping soundly, undisturbed by wolves or panthers, whose tracks we saw in the river sand, we prepared for the second day's march, that lay between the cliffs of Tolmie's Peak on the right, afterwards identified as the mountain ascended by Dr. Tolmie in September, 1833, and on the left the scarcely less imposing mass of Crescent Mt., as I named the volcano we had first seen.

The rapidly increasing fall of the river and the greater size of the boulders indicated the nearness of the glacier. Before noon we came upon it where the cliffs close in on either hand to a narrow gorge. It lay as a wall of ice, thirty to fifty feet high, across our path, and the river tumbled in little cascades out from a low cave in the centre. In the face, the snows of many winters were interstratified with the rock showers of as many summers, and the upper surface of this lowest end of the glacier, all its sharp lines melted off, was covered with a layer of rock and earth. I think there can be no better illustration of the advance of a glacier to the point, where the melting at its face balances the downward progress, than this worn, shrunken extremity, pressed on, as it is, by a vast accumulation of ice in the basin between Tacoma and Crescent Mt. It pushes no great terminal moraine before it. It meets with no obstruction, save the narrowness of the cañon; but, here in the shadow of the cliffs, the air currents from the west bid it halt. We found it too energetic in discharging volleys of stones,

for us to scale the face, and, having reconnoitred the neighborhood, we determined to ascend Crescent Mt., the following day. With the gathering darkness, Tacoma sent us a blast from his snow-fields that summer clothing could ill keep out, and against which all who would approach him, should provide. The lower part of our morning's ascent was up a steep but heavily wooded slope, which became more precipitous, as we climbed, until it narrowed to a rocky comb, where care was necessary lest we fall with some of the loosely balanced blocks into the ravines on either side. It led us to a grassy shoulder, on which we sprang out quickly. Instantly the air rang with shrill whistles. "The Indian chief!" "The happy hunting-grounds!" "The devil!" we exclaimed. But we soon discovered a "chief" scampering away as fast as his four legs would carry him to his hole, where, rising like a begging dog, he whistled before he disappeared. We were soon on the highest point of that southern rim of the crater, which commands a full view of Mt. Tacoma. Crescent Mt. is but one of the many volcanoes in the range, of which Tacoma is the central and the grandest peak. This volcanic range lies some miles west of the main Cascade chain, that is largely composed of sedimentary rocks, and is connected with it only by a spur thrown out from Mt. Tacoma's eastern slope. South of this spur, are the cañons of the Cowlitz. North of it, a basin drained by Carbon and White rivers. Here is the great glacial system, fed by slopes which descend 10,000 feet in five miles from the Liberty Cap, Tacoma's northern summit. Much too steep for snow to lie on, except on the highest shoulders where it packs to a depth of several hundred feet, the upper third of this tremendous height is bare black rock, on which the avalanches shatter into clouds of eddying smoke. The lower four miles are covered with a sheet of flashing ice, which pushes downward over the uneven surface, here carrying huge gleaming pinnacles aloft, there flowing in graceful curves like a river's current. Its western portion comes onward to the cliffs of Crescent Mt., nearly 3000 feet high, and turning from them sweeps down into the gorge of Carbon River; the eastern part extends a long tongue into a meadow brilliant with flowers, whence White River plunges into its unexplored cañon. This meadow is but one end of a green valley, that nestles strangely in this region of perpetual frost and sterile rocks, bounded on three sides by ice and snow, and on the fourth by forbidding precipices. It is only to be reached over one

of the glaciers or by a breakneck descent from the summit of Crescent Mt., which the well-worn paths of deer and white mountain goat show that they, at least, make in safety.



It was not till April, 1883, that I again had an opportunity to visit Mt. Tacoma. In the intervening months, explorations, sur-

veys and a horse trail had been extended in succession across the great Northwest Spur, that separates the Carbon and Puyallup rivers, and on the banks of the latter a large log house had been built, which "Billy," with his usual felicity, named "the Palace." Here he passed the winter with a picked crew, building a bridge, 250 feet long, across the river, and a house near the Palace for the "old man." This house was known as One Tree Hall, because its walls, partitions, flooring, roof and piazza were all split from a single cedar tree, which yielded boards, twelve feet long, two feet wide, and an inch thick, as even as if they had been sawed. But Billy's bridge was his pride, as it well deserved to be, and he watched it during the June freshets with a father's interest. The piers were of logs firmly bolted together and filled in with five or six tons of stone. They stood the trials of the spring well, and it was without any misgiving that Billy took two visitors to see the bridge one day in August, after a sudden rise of the river. They had walked as far as the second pier, Billy chatting easily of the beauties of the view, when one of the gentlemen asked: "Why didn't you fill this pier with stone too?" "We're going to fill it very soon, sir," was Billy's prompt reply, but he explained to me afterwards: "I couldn't belave the ividence of me two eyes, every stone washed out of it in a single night, and it a standin' like a rock."

The snow had scarcely melted at the Palace that spring, when Billy, Sam and myself started, with a fourth comrade, for the head of the Puyallup River,—before we reached the upper forks, it was two feet deep, and many were our tumbles on the smooth hidden boulders. I think there is no more characteristic view of Mt. Tacoma than that from the bed of the Puyallup, three miles above the Palace. The foreground is a slope of sombre firs; the distance, the graceful peak of the Liberty Cap soaring 12,000 feet into the heavens, girt by stupendous crags. From their base flows the North Puyallup Glacier, fed by avalanches whose whirling fall of 4000 feet is for each snowflake but a flash of individual sparkle in the sunlight between two long imprisonments in the nevé and glacier masses. Although it is but eight miles from the Palace to the southern or "Edmunds Glacier," which should be so-called, because our late vice-president visited it in the following June, it was late in the afternoon before we reached a point near the face. I struggled on through the deepening snow toward it, till warned

to back out by several heavy falls through the treacherous surface into holes among the great rocks, and by evidence of recent avalanches from the cliffs of columnar lava that form the southern wall of the cañon, 1500 to 2000 feet high.

Returning to where the boys were tramping down our beds for the night, I suggested removing to the forks, two and a half miles below, whence we could attack the northern or main Puyallup glacier in the morning. The proposition was hailed with delight, and it was not till several months later that I saw the Edmunds Glacier in its summer phase. It then showed a composite face, formed by three tongues, of which the southern or left hand extends half a mile further down the valley than the northern; before each tongue, lies a terminal moraine of considerable extent. Of comparatively small volume and very rapid descent, this glacier is an ice-fall, 5000 feet high, rather than an ice-current, and, beautiful as it is, does not impress one with the irresistible power of a flowing mass of rigid material.

On the following morning we were going to see the face of the North Glacier and return to the Palace by noon; but we reckoned without our host. Easy at first, the ascent soon grew steep; the river became a rushing torrent, and a dark gorge forced us to the southern bank; the northern was a precipice, Eagle Cliff, sheer as El Capitan in the Yosemite, and, as I afterwards found, over 1800 feet high. We crossed a milky branch, and struggled upward, ever upward, through deepening snow, now rescuing one another from unsuspected pitfalls, now combining forces to help Sam's great Newfoundland, Major. It was one o'clock when we reached the summit, the top of the terminal moraine, from which the glacier has receded several hundred yards, leaving a hollow where the snow lay in drifts. Opposite us stood a great black crag, behind which ice-pyramids 50 to 100 feet high were crowded in confusion; on the left they sloped away to the hollow; on the right they overhung the cliff, from which they fell in shattering masses. What a herald of freedom to the captive crystals is the crash of the ice pinnacles, splintering where they fall on the terminal moraine, and how the rivulets hurry away among the boulders down the cañons to the sea. Behind, lay the great ice-river that ends thus, 5000 feet above the sea; but the cliff before us shut out from our view all but the beautiful Liberty Cap.

We were a weary party when we reached the trail two and

a half miles above the Palace at seven that evening—but we had a race on foot. At one of the many fords we had separated, and each was trying to get home first. Favored by fortune, I reached the trail with fifty yards advantage and falling into the long lope, so soon learned under a pack in the woods, I led down the darkening forest vistas. Sam was pushing me hard, when I heard a rattle of coffeepot on fryingpan, as he pitched headlong. With derisive shout I sprang forward, put my foot under a root, and in my turn took a header into the soft moss; and together we burst into the Palace, where my boys were smoking their pipes before the bright blaze on the big hearth in the centre of the house, and the cook was washing up the supper dishes.

Five months passed by in exploration and trail building, and late in September I walked beside the "Little Lady of the Mountain," as she rode her dapple-gray mule, Pet, along the brow of Eagle Cliff. We had spent a day at Crater Lake, where nature has set an emerald seal on one of Pluto's sally-ports, and were on our way to the alp, through which Snowbrook dashes wildly down between its mossy banks to vanish in the vapor of Spray Fall, and gather itself again for its many tumbles toward the Puyallup. Our companion was the first lady to approach his Majesty, Tacoma, and he appeared to her glorified in a robe of transparent morning mist shot through with sunbeams.

We pitched the tent on the bank of Snowbrook, in one of the amphitheatres formed by the walls of a massive lava flow. Night comes with frosty touch up there near the stars; she silences all nature, save the voices of the brooks that call to each other from a hundred falls, and the heavens are as a black dome of polished metal studded with steady glowing lights.

Piercing the firmament, rises the phantom of a mountain, ethereal, unreal, the semblance of the Liberty Cap, yet not it, for it is suspended in a space of darkness, above, below, around it. As the circling zone of sunrise advances over the eastern plains, this vision of Tacoma seizes the shafts of light, and flings them into its cañons, driving darkness to cower in corners. All aglow with radiant gold and rosy blush, the grand mountain wakes to our day, an instant only of his life, and the ice fairies take up their task of gathering beneficent showers for the plant world from the warm south winds. Fortunately for us, they had other work to do, or took a holiday, when we made our ascent. At the snow

line, our lady took her place upon a sled facing down the mountain, her feet well braced, and wood to make a fire tied on behind her. With four on the tow-rope we went merrily up, now passing over tunnels, where the snow sounded hollow beneath our feet, now crossing the vanishing point of some crevasse ten or twelve feet wide and of unknown depth a short distance away. Up we went over the snowfield, on our left the nevé that feeds Carbon River, on our right the cliff that sinks to the North Puyallup; up, till we looked down on Crescent Mt., and far over its shoulders down White River and across to the Cascade range; up, between the Red Guardian and the Black, those jagged pinnacles that watch the traditional treasures of Mt. Tacoma, as the statues guarded those in the halls of the Alhambra; and up, till St. Helen's dome, forty miles away, was level with us, and we were on the narrow ridge that leads to the summit of the "Pyramid." Here the view swept westward over the dark sea of forest to the serrate Olympic range, northward to Mt. Baker, and into British Columbia; and eastward, beyond the jagged peaks of the Cascades, we saw the treeless plains of the Columbia river as a dun cloud on the horizon. In the evergreen monotone, the arms of the sound gleamed like silver lakes, but the work of man has made no mark as yet visible from the height. And southward we gazed up at cliffs of rock and snow, 4000 feet high, the wrinkled forehead that wears the Liberty Cap. From our feet flowed the glaciers of Carbon River and the North Puyallup; the first a broad snowy sheet, confined in its oval basin by the precipice of Crescent Mt.; the second, a direct current, falling 5000 feet in two and a half miles; the former flowing as a deep river, the latter fretting as a mountain torrent; the one crossed by long crevasses of intensely blue unfathomed depths, the other shattered into pyramids and pinnacles, and divided by off-branching chasms into sea-green ice sheets, linked by dainty arched bridges. Here we lingered many hours, and watched as nature's privileged lovers the play of light on clouds above us, and below, and on mountains far and near.

When at last we heeded the warning of the lengthening shadows to be gone, the hard snow was frozen and two of us had much ado to hold the sled, while Billy ran before to steer it. Away we went, running, leaping, sliding; now the cry was, "hold fast," with alpenstock and shoe-nails; now, "let her go," when the steepest pitch was passed. Such a coast! 3000 feet! Here a narrow arrête to steer

along, there a crevasse to edge around; and through the memory of it all rings the fair rider's joyous laughter.

A LETTER FROM PRESIDENT BARNARD.

READ AT THE ANNUAL MEETING OF THE ALUMNI OF COLUMBIA COLLEGE.

FREDERIC R. COUDERT, ESQ., PRESIDENT OF THE ALUMNI ASSOCIATION OF COLUMBIA COLLEGE.

MY DEAR SIR: Inasmuch as it is my misfortune to be deprived of the pleasure of meeting the Alumni of our college on the occasion of their annual festivity this evening, I desire, through you, to express to them my sincere thanks for their kind remembrance of me in their cordial invitation, and my regrets that it is not permitted to me to participate with them in their present revival of pleasant memories.

I wish further to offer them my warm congratulations upon the enviable record which our beloved college has left behind her in the past, the conspicuously brilliant position which she occupies in the present, and the flattering outlook which opens up before her in the immediate and distant future. The past history of our college is interwoven with the history of the country; and some of the brightest ornaments of our State and nation have received their earliest inspiration from her fostering care. In respect of years this history has extended over a period which begins to entitle her to rank among antiquities, at least as antiquities are reckoned upon the western continent. The academic year now passing is the one hundredth since her present governing board received its corporate existence; and, dating from the grant of the prerevolutionary royal charter, she is far advanced in her second century. To be merely ancient, however, is in human things not necessarily to be entitled to respect or admiration; but an antiquity of beneficence—a beneficence always enlarging and expanding from ancient down to modern times—is always truly venerable.

When antiquities are spoken of in other lands the term is usually understood to apply to visible structures, fashioned in forgotten years by human hands, but which, shattered by violence or wasted

by time, have been abandoned to sink into ruin. Of such antiquities we make no boast. Our historic horizon has not been wide enough to give room for them; but if it had been, our sturdy but earnest-minded progenitors, the early colonists on these shores, were too feeble in numbers and too simple in tastes to devote themselves to the rearing of grand architectural structures. They did better than that. They created institutions—institutions political, which formed the germ and nucleus of our free republican government; and institutions educational, out of which has grown that powerfully conservative influence, which, permeating the body politic, makes our freedom a blessing to us and not a curse. For the voice of history emphatically admonishes us that unbridled freedom is far from being an unqualified blessing to the human race.

Our fellow-citizens of New York have been recently engaged in a very imposing ceremonial—one which, for the time being, fixed the attention of all civilized mankind—the inauguration of the statue of "Liberty Enlightening the World." The conceit embodied in this remarkable work of art is beautiful, and the sentiment it is designed to convey is at once poetical and plausible; yet I do not hesitate to say, heterodoxical as the assertion may appear, that the conceit is a mistake and the sentiment is false. Liberty does not enlighten the world. It has never done so in the past and it will never do so in the future. It is knowledge which enlightens the world; and it is only in the light of knowledge that any liberty possible to man, consistently with the conservation of peace and social order, can live. Absolute personal liberty can only exist in a state of barbarism and ignorance, which is but another name for a state of violence and disorder. Just in proportion as the light of knowledge advances liberty is necessarily abridged; and it is only when it yields itself entirely to the salutary restraint of law that it brings with it the ideally perfect state.

Were I then invited to suggest an emblem of that true brightness by which the world is at once enlightened and blessed, I would propose to set upon a lofty pedestal a modest model of an American school-house—a little Parthenon without the columns and without the sculptures; and, in order that the æsthetic element might not be wanting, I would set beside it a figure of the goddess Athene, bearing in her hand a torch—fit emblem of that true light

which has guided the race in the obscure and difficult ways along which it has been wandering through protracted ages of darkness, until it has at last emerged into the full effulgence of our modern civilization.

That system of popular enlightenment which began in the country school-house has culminated in the great modern universities which adorn our land, among which can be found no brighter or more noble example than our own honored college. We may say of her truly, in the words of the great lyric poet of the Augustan age,

"*Micat inter omnes, velut inter ignes Luna minores.*"

But what she is in the present, or what she may have been in the past, is as nothing to what she will be in the future upon which she is now entering. Entering, I say, because her course is but begun. Her grand destiny is not to be perpetually engaged, as she has so long been, in the humble task of imparting to tyros and neophytes the mere elements of human knowledge, but in training men of mature and cultured intellects to the work of research and investigation, and in extending the boundaries of the field of knowledge itself. It is upon this magnificent career that she is just now entering. If, in following it, she shall receive that encouragement and support from her own children which she has a right to expect, and which they, I am sure, will willingly accord to her, nothing can prevent her advancing so rapidly to the front that long before her second century shall have rolled round she will stand universally confessed as the leading university of the western continent.

I am, my dear Mr. President,

Very respectfully yours,

F. A. P. BARNARD,

COLUMBIA COLLEGE, Dec. 14th, 1886. President of Columbia College.

ADDITIONS TO THE COLUMBIA COLLEGE LIBRARY IN THE DEPARTMENT OF NATURAL SCIENCE, USEFUL AND FINE ARTS. OCT.–DEC., 1886.*

I. ASTRONOMY.

COFFIN.—Solar and Lunar Eclipses.
GELPKE.—Oberflachen d. Weltkorpen und Sonnenge.
PETERS.—Astronomie and Verwandter Wiss.
SMISSEN.—Astrographie.
Astronomical Recreations.

II. BOTANY AND ZOOLOGY.

ARTHUR AND BARNES.—Handbook of Plant Dissection. 12mo. N. Y. 1866.
BAUMGARTNER.—Die Naturlehre. 3 vols.
CAMERON, J.—Gælic Names of Plants. 8vo. Edinburgh. 1883.
CANDOLLE, A DE.—Origin of Cultivated Plants. 8vo. N. Y. 1886.
COOKE, M. C.—British Fresh-Water Algæ. 8vo. London. 1882–84.
CORRESPONDENCE Botanique. 8vo. Liege. 1879.
DARBY, J. A.—Botany of the Southern States. 12mo. N. Y. 1866.
DRIERZON.—Bienen-zucht.
DUNCAN, P. M.—Transformation of Insects. 8vo. Philadelphia.
EICHELBERG.—Unterricht in der naturgeschichte.
FLORICULTURAL CABINET. 8vo. 27 vols. London. 1833-59.
FRANCHET ET SAVATIER.—Enumeratio Plantarum. 2 vols. 8vo. Paris. 1875–79.
GAUTIER, A.—Manuel des Plantes Médicinales. 8vo. Paris. 1822.
GRAY, S. O.—British Sea-Weed. 12mo. London. 1867.
HOOKER, W. J.—Niger Flora. 8vo. London. 1849.
HOPKINS, J.—Synopsis of American Plants. 12mo. Georgetown. 1814.
JOHNSON, L.—Manual of Medical Botany. 8vo. N. Y. 1884.
KLECMAN.—Handbuch des Gartenbaues.
KRAUSS, J.—Chlorophyllfarbstoff. 8vo. Stuttgart. 1872.
LOUDON, J. C.—Arboretum et Fructicetum Britanniæ. 8vo. 8 vols. London. 1854.
LUBEN.—Naturgeschichte.

* Readers' tickets can be obtained without difficulty by any one wishing to refer to books in the library.

MULLER, H.—Befruchtung der blumen durch insekte. 8vo. Leipzig. 1873.
NEES VON ESENBECK.—Floræ Africæ Australionis. 1841.
ROBINSON, W.—Hardy Flowers. 12mo. London. 1871.
SEEMAN, B.—Revision of the Natural Order of Hederaceæ. 8vo. London. 1868.
WIESNER.—Die entstehung des Chlorophylls. 8vo. Vienna. 1877.

III. CHEMISTRY.

BERZELIUS, J. J.—Lehrbuch de Chemie. 8vo. 10 vols. Dresden. 1835–41.
BOWMAN.—Medical Chemistry.
BUFF.—Stochiömetrie.
HERZEL.—Joiletten-Chemie.
LOURG.—Chemie d. Organ. Verbindungen.
PAYEN.—Populares handbuch industriel chemie.
SIMON, J. F.—Animal Chemistry. 8vo. London. 1845.
WEINLIG.—Die Pflanzenchemie.

IV. ENGINEERING.

BEAM'S Manual for Practical Surveyors.
BERNOULLE.—Vademecum des Mechanikers.
BOULTON, S. B.—Preservation of Timber. 12mo. N. Y. 1884.
CHREHORE.—Mechanics of the Girder. 8vo. Philadelphia. 1886.
HARRISON, J.—Locomotive Engine. 8vo. Philadelphia. 1872.
ITALIE.—Les Institutiones Sanitaire. 8vo. Milan. 1885.
JACQMIN, A.—Etudes sur les Chemins de fer des Pays Bas. 8vo. Paris. 1882.
PAMBOUR.—Locomotive Engines.
PICARD, A.—Les Chemins de fer Francais. 8vo. 6 vols. Paris. 1884.
SCHMAASE, C.—Geschicte d. bildenden Kunste. 8vo. 7 vols. Dresdenorf. 1866–79.
SHEDD, J. H.—Reports on Sewage in Providence. 8vo. Providence. 1874.
SMITH, H.—Hydraulics. N. Y. 1886.
WEISBACH.—Der Ingenieur.

V. GEOLOGY.

BANCROFT, C.—Footprints of Time. 8vo. Burlington. 1877.
FOSSETT, F.—Colorado, its Gold and Silver Mines. 8vo. N. Y. 1880.
KEEPING, W.—Fossils and Palæontological Affinities. 8vo. Cambridge. 1883.
LAING, S.—Prehistoric Remains of Caithness. 8vo. Edinburgh. 1866.
LE CONTE, J.—Compend of Geology. 12mo. N. Y. 1886.
MANTELL, G. A.—Geological Excursions round the Isle of Wight.

PENNSYLVANIA. — 2d Geological Survey. Reports C 5, F 2, K 4, R.R. 8. 4 vols. Harrisburg. 1884–85.
WINCHELL.—Walks and Talks in the Geological Field. 8vo. N. Y. 1886.

VI. MATHEMATICS.

ADAMS.—Harmonischen Verhaltnisse.
" Scholar's Arithmetic.
ALSOP.—Algebra.
ANGER.—Geometrie.
ARCHER.—d. Math. und Physik.
BALTZER.—Determinanten.
BONNYCASTLE.—Introduction to Algebra.
BEER.—Photometrischen Calculus.
BERKHAN.—Problem des Pappus.
BERNHAM.—Anwendung d. Algebra auf Arithmetic.
BLUMBERGER.—Theorieen aus d. Neuen Geom.
BRAVAIS.—Geom. Anordnung blatter u. blüth.
BRIDGE.—Three Conic Sections.
BRIOSCHI.—Theorie d. Determinanten.
CHASLES.—Cones of the Second Degree.
CREMONA, L.—Projective Geometry. 8vo. Oxford. 1885.
DAY.—Plane Trigonometry.
DREW.—Conic Sections. 7th ed.
" Solutions to Problems. 2d ed.
" On Probability.
EGEN.—Handbuch d. Allgemeine Arith. 2 vols.
EULER.—Anleitung zur Algebra.
FEIERBACH.—Geradlinigen dreiecks.
FERRERS.—Special Harmonics.
" Trilinear Coördinates.
FISCHER.—Mechanischen Naturlehre.
FORSYTH, A. R.—Differential Equations. 8vo. London. 1885.
FROST.—Newton's Principia.
GREENLEAF.—Algebra and Key.
HARRIS, P. H.—Theory of Determinants. 8vo. Boston. 1866.
HASSLER.—Analytic Trigonometry.
HELLURG.—Problem des Apollonius.
HERSCH.—Buchstabenrechnung und Algebra.
HUTTON.—Compendious Measurer.
KAYSER.—Handbuch d. Mechanik.
" La Figure de la Terre.
KUNZ.—Lehrbuch der Geometrie.
LA CROIX.—Calcul des Probabilities.
LAWRENCE.—Primary Algebra.
" Elements of Algebra.
LORENS.—Grundriss d. Mathematik.
MAYER.—Practischen Geometrie. 3 vols.
MULLER.—Mathematical Questions. 11 vols.
NAUMANN.—Polaritatsgesetze.
NEWTON.—Principia.

PAULUS.—Grundlin en ebenen Geometrie.
PERKINS.—Geometry.
PLUCKEN.—Analytisch-Geom. Entwicklungen. 2 vols.
RUNKLE.—Mathematical Monthly. 2 vols.
SALMON.—Conic Sections. 4th ed.
" Modern Higher Algebra.
SCHEFFLER.—Verhaltniss d. Arith. zur Geometrie.
SCHINTZLER.—Aufgaben aus d. Differential Rechnung.
SCHLONELCH.—Analytische Studien.
" Analytischen Geometrie.
" Hoheren Analysis.
SCHORRE.—Die Conchorde.
SCHWARRZ.—Zahlen-theorie.
STANDT.—Geometrie der Lage.
STERN.—Auflosung d. Transcendenten Gleichun.
THENOT.—Practical Perspective.
THOMAS.—Pythagoraische Dreieck.
TOWNSEND.—Modern Geometry.
WHITWORTH.—Trilinear Coördinates.
WITZCHELL.—Grundsen d. Neulieren Geometrie.
WRIGHT.—Modern Geometry.

VII. METALLURGY.

KUNHARDT, W. B.—Practice of Ore Dressing in Europe. 8vo. N. Y. 1884.
STREETER, E. W.—Gold. 8vo. London. 1877.

VIII. MINERALOGY.

CANADA.—Descriptive Catalogue of Economic Minerals of Canada. 8vo. London. 1886.
CHESTER, A. N.—Catalogue of Minerals. 8vo. N. Y. 1886.
GRAILICH.—Krystallographisch-Optische.
GRAILICH UND LAING.—Physicalischen Verhaltnisse d. Kryrs. Korper.
HUSSEK, E.—Determination of Rock-Forming Minerals. 8vo. N. Y. 1886.
KREUTZER.—Krystall-flachen und Netze.
NAUMANN.—Mineralogie Atlas.
WADSWORTH, M. E —Lithological Studies. 8vo. Cambridge. 1884.

IX. PHYSICS AND METEOROLOGY.

BENJAMIN, P.—Age of Electricity. 12mo. N. Y. 1886.
EULER.—Letters of, on Natural Philosophy. 2 vols.
EVERETT, J. D.—Units and Physical Constants. 12mo. London. 1886.
FLIEDNER.—Aufgaben aus der physik.
GRUNERT.—Meteorologischen Optik.
HERSCHEL.—Vom Licht.
KAHL.—Mathematische aufg. aus der physik. 2 vols.

KORSCHEL.—Bary's neues physikalische problems.
SCHELLING.—Naturphilosophie.
SCHLEINMACHER.—Analytische Optik.
ZAMMINER, F.—Musik u. Akustik.

X. MISCELLANEOUS.

ARNOLD, A.—History of the Cotton Famine. 12mo. London. 1865.
CORNIL ET BABES.—Les Bacteries. 8vo. Paris. 1886.
CUTTER's Anatomy and Physiology.
DONNELL, E. J.—Statistical History of Cotton. 8vo. N. Y. 1872.
HEIMCHEN.—Wiedersehen.
HEINZELMANN.—Polarische gegensatz in der Music.
HERMSTADT.—Raithgeber.
HODGINS, J. G.—School Architecture and Hygiene. 8vo. Toronto. 1886.
KANT.—Schönen u Erhabenen.
LINDLEY, J.—Rosarium Monographia. 8vo. London. 1820.
LITTROW.—Chronographie.
RAFINESQUE, C. S.—Florula Ludonciana. 8vo. N. Y. 1817.
RECUEIL des lois decrets. 8vo. 2 vols. Paris. 1856–57.
ROGERS, A.—Law Relating to Mines. 8vo. London. 1864.
SCHULZ.—Mathematischen Geographie.
SCHWANN, T.—Microscopical Researches. 8vo. London. 1847.
SELTEN.—Geographie.
SIMMS.—Mathematical Instruments.
SWEET, K.—Cistineæ. 8vo. London. 1825–30.
TEXAS.—Resources of Soil and Climate. Pamphlets. Galveston. 1882.
TROUESSART, E. L.—Microbes, Ferments and Moulds. 12mo. N. Y. 1866.
WIEGAND.—Grundriss d. Math. Geog. 4th ed.

INDEX OF CURRENT LITERATURE RELATING TO AMERICAN GEOLOGY.*

BY F. J. H. MERRILL.

AMERICAN ASSOCIATION, Brief Notices of Papers read before the. Wm. M. Davis. *Am. Jour. Sci.*, III., vol. xxxii., p. 319.

APATITE. Notes on Canadian Fluor-Apatite, or Fluor-Phosphate of Lime. F. J. Falding. *Eng. and Min. Jour.*, vol. xiii., pp. 383, 402.

CALIFORNIA. The Latest Volcanic Eruption in Northern, and its Peculiar Lava. J. S. Diller. *Am. Jour. Sci.*, III., xxxiii., p. 45.

CANADA. Descriptive Catalogue of a Collection of the Economic Minerals of. By the Geological Corps. H. R. C. Selwyn, LL.D., F.R.S., etc., Director. Colonial and Indian Exhibition. London. 1886.

COLORADO. A Remarkable Extinct Geyser Basin in Southwestern. T. B. Comstock. *Am. Nat.*, vol. xx., p. 963.

COLORADO. Geology and Vein Structure of Southwestern. T. B. Comstock. *Trans. Am. Inst. M. E.*, vol. xv. *Am. Nat.*, vol. xx. p. 1043.

COLUMBIA COUNTY, N. Y. Fossiliferous Limestones of, and their Relations to the Hudson R. Shales and the Taconic System. I. P. Bishop. *Am. Jour. Sci.*, III., xxxii., p. 433.

DIAMOND, Genesis of the. J. S. Diller. *Science*, vol. viii., p. 392.

DRIFT OF THE ROCKY MTS. Some Peculiarities of the Local. T. B. Comstock. *Am. Nat.*, vol. xx., p. 925.

GLACIATION of North America, Great Britain and Ireland, Comparative Studies upon the. H. Carvill Lewis. *Am. Jour. Science*, III., xxxii., p. 433. *Am. Nat.*, vol. xx., p. 919.

GLACIER. The Muir. G. Frederick Wright. *Am. Jour. Sci.*, III., xxxiii., p. 1.

GNEISSIC FOLIATION, and Schistose Cleavage in Dykes, and their Bearing upon the Problem of the Origin of the Archæan Rocks. Some Instances of. A. C. Lawson. *Proceed. Can. Inst. of Toronto*, 3d series, vol. iv.

KANSAS. A Giant Armadillo from the Miocene of. *Am. Nat.*, vol. xx., p. 1044.

LAKE CHAMPLAIN.—Notice of Geological Investigations along the Eastern Shore of. Made by Prof. H. M. Seely, and Pres. Ezra Brainerd. R. P. Whitfield. *Am. Nat.*, vol. xx., p. 1041.

LAKE SUPERIOR REGION. Ferruginous Schists and Iron Ores of the. R. D. Irving. *Am. Jour. Sci.*, III., vol. xxxii., pp. 255–272.

LAND-SLIDE. A Remarkable. *Science*, vol. viii., p. 293.

---

* Beginning October 1, 1886.

LITHOPHYSÆ, The Nature and Origin of, and the Lamination of Acid Lavas. J. P. Iddings. *Am. Jour. Sci.*, III., xxxiii., p. 36.

LONG ISLAND, Geology of. *Science*, vol. viii., p. 352.

MAP OF THE U. S., Geological. C. H. Hitchcock. *Trans. Am. Inst. M. E.*, vol. xv.

MEXICO, Sierra Mojada, Geology of. R. E. Chism. *Trans. Am. Inst. M. E.*, vol. xv.

MISSOURI, Historic Memoir on the Geological Surveys of. G. C. Broadhead. *Trans. Acad. Sci.*, St. Louis, vol. iv., p. 611.

NATURAL GAS in the United States, Geological distribution of. C. H. Ashburner. *Eng. and Min. Jour*, vol. xlii., p. 332.

NOMENCLATURE, Geological. Meeting of the International Committee at Geneva. J. D. Dana. *Am. Jour. Sci.*, III., xxxii., p. 406.

NORTH ATLANTIC Oceanic Basin, Geological age of, and Origin of Eastern America. J. D. Dana. *Am. Jour. Sci.*, III., vol. xxxii., p. 406.

ORE DEPOSITS, The Genesis of certain. S. F. Emmons. *Trans. Am. Inst. M. E.*, vol. xv.

PENNSYLVANIA, Annual Report of the Geological Survey for 1885. *Am. Jour Sci.*, III., xxxii., p. 408.

RIO GRANDE, Age of Coal Found in the Region Traversed by the. C. A. White. *Am. Jour. Sci.*, III., xxxiii., p. 18.

ROCKS, The Texture of Massive. G. F. Becker. *Am. Jour. Sci.*, III., xxxiii., p. 50.

ROCKS, Washoe. G. F. Becker. *Bull. Cal. Acad. Sci.*, Nov., 1886.

SEA LEVEL and Ocean currents. J. S. Newberry. *Science*, vol. viii., p. 391.

TRAP and Sandstone in the Gorge of the Farmington River at Tariffville, Conn., On the. Wm. A. Rice. *Am. Jour. Sci.*, III., xxxii., p. 430.

TRIASSIC Formation of the Connecticut Valley, The Structure of. Wm. M. Davis. *Am. Jour. Sci.*, III., xxxii., p. 342.

UPPER SILURIAN, New England. T. Nelson Dale. *Proceed. Can. Inst. of Toronto*, Series III., vol. iv., p. 69.

VOLCANIC MOUNTAIN, A Dissected, some of its Revelations. J. D. Dana. *Am. Jour. Sci.*, III., xxxii., p. 247.

PROFESSIONAL NOTES.

Liquid Oxygen, Nitrogen, and Carbonic Oxide.

Some very interesting experiments in liquefying oxygen, nitrogen, and carbonic oxide have been made, within the last two years, by Messrs. Sr. Wroblewski and C. Olszewski, in the Physical Institute of the University of Cracow, and the results have been published in Poggendorff's Annalen (*Ann. d. Physic. Chem., N. F.*, Bd. xx , p. 243).

The first attempts to liquefy these gases were made by Collodon, in 1828, and also by Faraday and Natterer. In 1877 Cailletet and Pictet succeeded in making liquid oxygen. When Pictet opened the stop-cock of his metallic receiver, which had been cooled by liquid carbonic acid, under a pressure of 450 atmospheres, a liquid stream of oxygen was forced out with great vehemence, and it turned into gas immediately. Cailletet compressed oxygen, nitrogen, and carbonic oxide in glass tubes, with a pressure of 300 atmospheres, at —29° C. Breaking the tubes, he noticed a distinct fog, due to the liquid particles of these gases. Cailletet tried the same experiments, using liquid æthylen to produce a still lower temperature, but he was not as successful as in the first set. These experiments showed the possibility of liquefying these gases, but did not prove it absolutely.

Messrs. Wroblewski and Olszewski, with the assistance of Mr. E. Ducretet, of Paris, manufactured an air-tight piece of apparatus, capable of standing a pressure of over 500 atmospheres. The high pressure was produced by the use of a Bianchi air-pump. The extreme low temperatures were taken by the hydrogen-thermometer, and also with the thermo-electric thermometer. The following are some of the results of these experiments.

CS_2 solidifies at —116° C., and melts at —110° C. 95 per cent. alcohol produced a thick oil at —129° C., and a solid white mass at about —130.5° C. PCl_3 solidifies at —112° C.

With a pressure of about 2.5 mm., as shown on the manometer of the pump, the lowest temperature produced was —139° C.

Natterer claimed to have produced a temperature of —140° C. with liquid nitrousoxide and carbon disulphide, but this is shown to be incorrect, by the fact that CS_2 solidifies at —116° C.

On cooling to —130° C. with a pressure of 20 atmospheres, it was found that oxygen liquefied completely, to a colorless fluid of great mobility, the whole mass of which boiled immediately on taking off part of the pressure.

The liquefying of nitrogen and carbonic oxide is far more difficult than that of oxygen. At —135° C. and a pressure of 150 atmospheres, these gases do not become liquid. If the pressure be released suddenly the nitrogen is transformed to a boiling liquid, showing the same phenomenon as the one seen with carbonic acid liquefied in a Natterer's tube, which gives a fog when the tube is placed into hot water, and then

broken. Carbonic oxide does not boil as violently as the nitrogen. If the expansion is not rapid, and the pressure only about 50 atmospheres, both nitrogen and carbonic oxide are transformed completely into colorless and transparent liquids. To keep them in this condition for some time, a temperature lower than any yet attained is required. Wroblewski determined the vapor density of oxygen to be 0.89 to 0.90 at —130° C., the critical temperature as —113° C., and the critical pressure as 50 atmospheres. The figures calculated by E. Sarrau are —105° C., and 48.7 atmospheres pressure.

Continuing these experiments (*C. R.* 99, p. 606; 100, p. 350) Olszewski examined the liquid, transparent, colorless carbonic oxide produced at —139.5° C. and 35.5 atmospheres pressure, and determined the following critical temperatures up to its freezing point:

At pressure of	25.7	atmospheres.	Critical temp. = —145.3° C.
"	20.4	"	" —150.0° "
"	14.8	"	" —155.7° "
"	6.3	"	" —168.2° "
"	4.6	"	" —172.0° "
"	1.	"	" —190.0° "

At a pressure of 100 mm., and a temperature of —207° C., carbonic oxide began to solidify. With a still lower temperature, —211°, and a pressure of about 60 mm., it formed a compact solid, of snowy appearance, which seemed transparent if the liquid was not allowed to boil, but only to evaporate slowly in a vacuum. On increasing the pressure the substance was transformed into a colorless liquid. The critical point of nitrogen was found to be —146° C., at a pressure of 35 atmospheres. At a pressure of 60 mm. and a temperature of —214° C., it began to solidify. When the pressure was reduced to 4 mm., the temperature, taken with the hydrogen thermometer, was found to be —225° C., being the lowest temperature ever obtained in the laboratory.

With oxygen the following critical temperatures were determined:

Pressure of	50.8	atm.	Critical temperature = —118.8° C.
"	40.4	"	" " —125.6° "
"	32.6	"	" " —130.6° "
"	10.25	"	" " —151.6° "
"	4.25	"	" " —166.1° "
"	1.	"	" " —181.0° "
"	9 mm.	"	" " —211.5° "

At 4 mm. pressure and a temperature below —211.5° C., the liquid oxygen showed no signs of solidifying. Liquid oxygen is, therefore, one of the best cooling mixtures.

Experiments by Wroblewski (*J. pr. Ch.*, Aug., 1885) showed that oxygen does not solidify if it is made to boil by suddenly releasing the pressure. But in this case a crystalline residue remains behind, on the bottom of the apparatus, or on any body placed in it. Whether these are crystals of oxygen or impurities in the gas, has as yet not been

determined. This separation of crystals injures, to some extent, its use as a cooling mixture. Other obstacles to overcome are the difficulty of obtaining perfectly air-tight apparatus, and the short duration of the boiling point of the liquids after releasing the pressure, at which time the temperature must be taken. The temperature of boiling oxygen was found to be —186° C., measured with a thermo-electric thermometer. Dewar (*Chem. and Drgst.*, Nov., 1885) determined the density of liquid oxygen to be 0.65. Dewar recommends liquid marsh gas as the best cooling mixture to liquefy heavy gases capable of being condensed.

EDWARD GUDEMAN.

"Siphon Tap Case."

On April 19, 1886, the United States Supreme Court, in the case of Keyes and Arents *v.* Grant, rendered a decision reversing the judgment entered upon a verdict, rendered in the Colorado Circuit, for the defendant, upon the direction of Judge Hallett, and sending the case back for a new trial. This was the famous "Siphon Tap Case," based upon Arents' Patent, No. 121,385, of Nov. 28, 1871. The defences relied upon chiefly were, (1) Anticipation by descriptions found in J. B. Karsten's "*System der Metallurgie*," published at Berlin, in 1831; (2) That in view of the state of the art at the date of the alleged invention the improvement was not patentable, as it did not require the exercise of invention.

The plaintiffs called various experts to show the ordinary way of tapping prior to the introduction of the Siphon Tap, also to show the improvement which it was over the old method, and also to show the sufficiency of the description contained in the patent. For the purpose of showing the old style of tapping a model was introduced and various experts, including Arents, testified to its correctness. The defendants introduced extracts from the text and plates of Karsten, and produced experts, who testified that Karsten's furnace would do the same work, and one of the defendants testified that he had, many years before the issue of Arents' patent, built an experimental furnace of small size, according to Karsten's description, and that it had worked successfully. The plaintiffs then produced evidence to show that the Arents' furnace and tap differed materially from that shown by Karsten and that constructed by the defendant. Judge Hallett thereupon directed a verdict for the defendants. The appellate court held where the defendant in a suit for infringement of a patent sets up a prior publication of a machine, anticipating the patented invention, and it appears that there are obvious differences between the two machines, in the arrangement of the separate parts, in the relation of the parts to each other, and in their connection with each other in performing the functions for which the machine is intended, and experts differ upon the question whether these differences are material as to the results, and whether they required the faculty of invention, these questions are questions of fact, to be left to the determination of the jury under proper instructions from the court.

The case is now sent back for a new trial. I am inclined, however, to believe that the plaintiffs will be very loath to press the case on to trial in view of what the defendants have set up.

[Since writing the foregoing I have been informed that the case has been settled and that the defendants have allowed judgment affirming the patent to be entered for the plaintiffs, who are now demanding royalties and past damages from all persons using the siphon tap. This is probably due to the fact that the defendants have not been able to secure the necessary coöperation from other infringers to enable them to defend the suits anew, and have deemed it wise to compromise rather than to carry on the litigation single-handed. I should be inclined to assume that if any infringer resisted and a suit against him should be won by the plaintiffs on the merits, any settlement that would be made would have to be on terms very favorable to the infringers.] W. P. B.

Amer. Metrological Society.

At the annual meeting the following officers, etc., were elected:

OFFICERS FOR 1887.—*President*, F. A. P. Barnard, S.T.D., I.L.D., L.H.D., President of Columbia College; *Vice-President*, Prof. E. N. Horsford, Harvard College; *Rec. Secretary*, Melvil Dewey, Librarian Columbia College; *Cor. Secretary*, Alfred Colin, New York; *Treasurer*, Prof. J. K. Rees, Columbia College.

Council.—T. R. Pynchon, LL D., Hartford, Conn.; E. B. Elliott, Gov't Actuary, Treas. Dept., Washington; A. W. Wright, Yale College; E. B. Coxe, Drifton, Penn.; R. W. Raymond, New York; W. E. Dodge, New York; Henry Holt, New York; N. M. Beckwith, New York; W. F. Allen, New York; R. B. Fairbairn, D.D., Annandale, N. Y.

Advisory Committee.—J. W. Powell, Washington, D. C.; E. Loomis, Yale College; F. L. Olmsted, Brookline, Mass.; James B. Eads, St. Louis, Mo.; Sandford Fleming, LL.D., Ottawa, Canada; T. C. Mendenhall, Terre Haute, Ind.; W. B. Hazen, Washington, D. C.

We are glad to lay before our readers the following letters which will be of interest to most engineers:

GENERAL TIME CONVENTION. OFFICE OF THE SECRETARY, No. 46 Bond St., New York, December 29, 1886.

PROF. J. K. REES, SEC. AMERICAN METROLOGICAL SOCIETY, COLUMBIA COLLEGE, N. Y.

MY DEAR SIR:—I send you herewith a map prepared for the use of the Committee on Uniform Train Rules of the General Time Convention, showing the centres from which Standard Time is daily furnished, and the lines over which it is disseminated from each centre.

The Committee above mentioned has recommended that Standard Time be sent out over all the railway lines of the United States at the same moment of time daily, the hour recommended being 4 P.M., Central Standard Time.

As Secretary of the General Time Convention I am at present engaged in quite an extensive correspondence with a view to bringing about the adoption of Standard Time by those cities which still adhere to their local time. This movement has already resulted in success in

two instances. In Belfast, Me., Eastern Time was adopted on Dec. 15, 1886, the clocks being set twenty-four minutes slow; and in Pittsburgh, Penn., where an ordinance has been passed adopting Eastern Standard Time from Jan. 1, 1887, when the clocks will be set twenty minutes fast. In Belfast the change was principally due to the efforts of Mr. Charles A. Pilsbury, Editor of the *Republican Journal*, and in Pittsburgh to Mr. Robert Pitcairn, Superintendent and General Agent of the Pennsylvania Railroad.

It is probable that the Legislature of Maine will pass a law at its coming session making Eastern Time the standard for the State.

Correspondence with the superintendents of public schools, in a number of the cities of Ohio, has developed the fact that a strong feeling in favor of the adoption of Standard Time exists in that State, from which favorable action is likely to come in the near future.

The twenty-four o'clock scale is in use upon the Canadian Pacific Railway west of Winnipeg, upon the Manitoba and Northwestern Railway, and upon the Idaho Division of the Union Pacific Railway. It is proposed to adopt it soon on all the divisions of the Union Pacific Railway.

Under instructions from the General Time Convention I am preparing and will shortly issue a circular asking the views of the leading railway officials on the subject of the general adoption of this scale for employes' time-tables and advertisements. Yours truly,

(Signed) W. F. ALLEN.

OTTAWA, December 25, 1886.

DR. F. A. P. BARNARD, PRES'T AMERICAN METROLOGICAL SOCIETY.

DEAR SIR:—Allow me to offer a few words repecting the progress which has been made in time reform during the past year. The movement has undoubtedly found an able supporter in Mr. W. H. M. Christie, the English Astronomer Royal. That gentleman has given great prominence to the question in a recent lecture before the Royal Institution of Great Britain, and the influence of his writings must have an advantageous effect far and wide. In this country, Standard Time, according to the meridians which are multiples of 15° from Greenwich, has been formally established, and has proved of incalculable benefit to the whole community. Another step in the general reform has been initiated: the twenty-four hour system has been put in practice on at least about two thousand miles of railway, with extremely satisfactory results. For the past six months the railway stretching from Lake Superior through Canada to the Pacific coast has been operated on the twenty-four hour system. The towns and villages along the line have with great unanimity accepted the change, and not a single voice has been heard in any quarter expressing a desire to return to the old usage. So satisfactory in every way has the new system proved that the Canadian Pacific Railway Company have decided to extend its application eastward to Ontario and the valley of the St. Lawrence. The branch and connecting lines are following the same course, and I am assured that by the end of next year the twenty-four hour system will be in common use by the railways from Halifax in Novia Scotia to Vancouver on the Pacific coast. You are, no doubt, already aware that the twenty-

four hour system is in use throughout the extensive lines of telegraph between Great Britain, Egypt, India, South Africa, China, and Australia and New Zealand.

However important these changes are, they can only be viewed as provisional steps in the general unification of time throughout the world. They are means to an end, and the great end of the movement is the universal adoption of a new notation of time which will be common to all nations. It is only step by step, and by familiarizing men's minds with the new ideas that the larger reform can be accomplished. With this end in view, the Smithsonian Institution, desiring to coöperate in the movement, have agreed to publish and circulate in all countries where their reports are sent, a paper on Time Reckoning for the Twentieth Century, advance sheets of which I now forward to you.

This question has an educational interest, and such being the case, I am inclined to think that much good could be done by appealing to the educational institutions. Probably the most effective means of influencing the rising generation of this country would be to bring the subject under the notice of the public schools. If the children of both sexes were taught the true principles of time reckoning, in a very few years their influence would be felt, and the main obstacle in the way of adopting a common notation would disappear throughout this continent. I venture to suggest, therefore, that the Society would in the highest degree advance the important movement by taking such steps as may be deemed necessary and proper, to bring the question to the notice of the Superintendent of Education in each State, with the view of reaching each boy and girl of school age between the two oceans.

If America takes the lead in this matter I do not doubt that the other continents will follow in good time.

I am, with great esteem,
Very truly yours,
(Signed) SANDFORD FLEMING.

SCHOOL OF MINES, COLUMBIA COLLEGE,
NEW YORK, February 5, 1887.

EDITORS QUARTERLY:

My article on Earthquakes, which appeared in the last issue of the QUARTERLY, was written hurriedly by dictation, and was printed when I was too ill to give proper attention to the proof-reading. As a consequence some obvious, and, therefore, mortifying, though otherwise unimportant errors, somehow found their way into it. On pages 5 and 14 the gravity pressure of a column of rock one mile in height should be 792,000 pounds, and that of a column one hundred miles high 7,920,000 pounds, instead of the numbers given. Doubtless most persons who have read the article have detected the arithmetical error, but all who have copies of the October number of the QUARTERLY will do themselves and me a service by erasing the wrong and substituting the right figures. Another error is the spelling of the name of the great physicist, Sir William Thomson, with a p. This, also, is a consequence of composing by dictation.

J. S. NEWBERRY.

ABSTRACTS.

The Lick Observatory (*New York Tribune, Aug.* 29, 1886).

The observatory, for which Mr. James Lick gave $700,000 in 1875, is now nearly completed, and another year will bring it to its final state. Some time during 1887 the Lick trustees expect to transfer to the Regents of the University of California the reservation of 1600 acres, with the small village which has grown up upon it since the beginning of the undertaking. The little white houses and workshops which have been used for the accommodation of the employés are nestled together on a narrow saddle just below the Observatory Peak proper. They have grown by a process of accretion from the original one-room cabin which was put up in 1879. At that time, the observatory itself was a small dome some ten feet in diameter, perched insecurely on a narrow ridge between two sharp points of rock at the summit. This little dome covered a six-inch equatorial belonging to Mr. Burnham, the distinguished observer of double stars. Mr. Burnham was invited by the Lick trustees to bring his telescope from Chicago and to observe double stars for several months at Mount Hamilton, in order to prove the superiority of this elevated mountain peak for astronomical purposes over a less elevated position in the interior. Experience showed, in the most satisfactory manner, that the site chosen for the Lick Observatory was a most fortunate one. Not only are three-fourths of the year uninterruptedly clear, but the steadiness of vision, the absence of twinkling of the stars, allows the most delicate and most precise observations to be made in far greater number than at any other observatory site in the United States, or in the world. The undertaking of founding the observatory was begun in a truly scientific manner by this test, and all the work done since has been executed in the same spirit. Nothing has been built for mere show, and yet no expense, however lavish, has been spared to make the whole observatory buildings, instruments and equipment perfect.

After Mr. Burnham's examination had shown that Mount Hamilton was eminently fitted to be the site of an observatory of the first class, which was to contain, according to Mr. Lick's bequest, "the most powerful telescope in the world," work was begun in real earnest, and has been continued in the same earnestness up to to-day. Captain Floyd and Mr. Fraser visited Washington in 1880, and in consultation with Professor Newcomb and myself agreed upon a plan for the buildings, and upon the chief instruments to be bought. The details have been settled from time to time as necessity arose. It was found that in order to get a level platform, large enough for the instruments and buildings to stand upon, 150,000,000 pounds of the hard rock of the summit had to be blasted away and tumbled over the edge. Several miles of very difficult roads had to be built in order to reach the various peaks where reservoirs were to be placed, and the springs which gave

the water-supply. Santa Clara County generously made the magnificent mountain road from San Jose to the summit (twenty-six miles), at a cost of $78,000. The Government of the United States gave us a reservation of 1350 acres, to which the trustees added by purchase 150, and to which Robert Morrow, Esq., has added some fifty acres by gift.

Mr. Lick's first idea was to establish his observatory at Lake Tahoe, but the severity of the winters there, and especially the great snowfall, caused him quickly to abandon this plan. The question then was, which one of the mountain peaks in California to select. The very high mountains cause the formation of clouds, and therefore the high ranges were abandoned. The mountain selected had to be in the Monte Diablo range, for the Coast range is affected with the dense sea fogs. The choice was finally narrowed down to a selection between St. Helena mountain, Monte Diablo, Loma Prieta and one of the three peaks of the mountain mass called Hamilton. The Spaniards called this group of three peaks Santa Isabel. This name is now confined to a grand rounded mass two miles east of the observatory. The east peak (now called Mount Copernicus) was a mile further from San Jose than Observatory Peak, although a very little higher (4448 feet). Mount Kepler (4318 feet) lay between the two, and was utilized as a station for a reservoir. The Observatory Peak is 4302 feet after being levelled.

Seven years ago there was only a trail over the mountain, which was unvisited except by hunters. Now, there are strong low buildings all around, full of beautiful instruments which represent the very finest and most delicate mechanical conceptions. And all these have been brought from various parts of the world, and have met and fitted together with perfect precision. The clocks from Amsterdam and London are side by side with meridian instruments from Hamburg and Washington.

One thing is especially interesting in this. The object-glass of each of the telescopes—that part which is peculiarly the result of the highest degree of mechanical and artistic skill—is from the shop of Alvan Clark, in Cambridgeport, Massachusetts. It is from the Clarks that the large object-glasses come which are mounted in the great telescopes of Chicago (eighteen inches); Princeton (twenty-three inches); Washington (twenty-six inches); St. Petersburg (thirty inches), and the thirty-six-inch objective of the Lick Observatory will also be made by the same skilful hands. This objective will have an important advantage over the others, apart from the two capital advantages of its elevated situation and its superior size. Like them it will have two lenses, a crown and a flint, which will together bring the rays by which we see to a focus, so that as a seeing telescope it is their superior. But it will also have a third (crown) lens which can be placed in front of (and close against) the other two, so that the three will bring the rays by which we photograph to a single focus. Thus the great telescope can, at will, be turned into a great camera, and the painful micrometric measures by which astronomers register the relative positions of stars and planets can, in many cases, be replaced by photographs which give permanent and automatic records of these positions.

The art of applying photography to astronomy is a new one. It has received the most splendid developments from the astronomers of the Paris Observatory (and from others in this country, notably from Dr. Lewis Rutherfurd and Dr. Henry Draper of New York), but the oppor-

tunities afforded by the Lick refractor in its exceptional situation are simply boundless. A single exposure will give us a map of the sky comprising four square degrees on a plate 24 by 24 inches. A few minutes will impress on this plate a permanent record of the position and brightness of all the stars visible in even the largest telescopes. A comparison of two such plates, taken on different nights, will point out any changes which might easily escape the most minute observation by other methods. The sun's image unmagnified will be six inches in diameter; a large sunspot will be the size of your finger nail. Beautiful photographs of the planets can be taken so as to register with perfect accuracy the features of their surfaces. Comets and nebulæ can be studied at leisure, as one studies a copperplate engraving, from their automatic registers. The variations of refraction from the horizon to the zenith can be made to record themselves for measurement. There is absolutely no end to the problems lying close at hand, and their number and importance will develop. There is no question but that the large telescope, with its two objectives, in its absolutely perfect site, is the most important astronomical instrument in the world.

Mr. Lick's bequest for the observatory was $700,000, of which some $200,000 will remain after the observatory is completed. The income from this sum must support the observatory for the present. Although the whole plan of the observatory has been made with direct reference to keep its running expenses low, it is clear that the company of astronomers will have to be kept small—far too small to utilize the instruments to the full. It would require a staff of at least ten astronomers to return the full results from the beautiful outfit, and at present not more than three can be employed. The work of these must be concentrated on the large equatorial, and even then their energies will not be sufficient to utilize every moment. We do not mean to jealously guard the immense scientific opportunity for ourselves, for California, or even for the United States. The real gift of Mr. Lick was to the world. We mean to put the large telescope at the disposition of the world, by inviting its most distinguished astronomers to visit us, one at a time, and to give to them the use of the instrument during certain specific hours of the twenty-four. Each day there will be certain hours set apart when the observatory staff will relinquish the use of the equatorial to distinguished specialists who will come from the United States and from Europe to solve or attack one of the many unsolved problems of astronomy. In this way we hope to make the gift of Mr. Lick one which is truly a gift to science, and not merely a gift to California and its University.

Even under such circumstances it will be impossible to utilize the instrumental outfit to the full. It was clearly the duty of the Lick trustees to make this observatory perfect in every respect, and to provide it with all the instruments necessary to a complete equipment. This they have done economically and wisely. So far as I can judge there is nothing that should be altered. The instruments are all necessary, and they are all mounted in the most perfect manner. This is especially true of the great equatorial. The objective itself is unequalled. It has cost $52,000. The photographic lens will add $13,000 to this. The mounting, which is to carry the tube of nearly sixty feet in length, has been studied in every detail by the contractors, Messrs. Warner & Swasey, of Cleveland. I believe this mounting, which they are to make

and deliver for $42,000, will be at least equal to the best European mountings. It costs $15,000 less, and is to be delivered in one-third of the time. The dome, of seventy feet interior diameter, will be built by the Union Iron Works of San Francisco, and I have no doubt that it will be materially better than any now made. The computations for the dome were made by Professor Bull, of Madison, Wis., and many important additions have been made by the contractor and by Mr. Fraser. The chief novelty will be the adoption of Mr. Grubb's ingenious plan for placing the observer in a proper position with reference to his telescope. We have to recollect that the eye-piece of the telescope may be about five feet from the base of the dome when the telescope is pointed to the zenith, or it may be thirty-five feet in the horizontal position. The ordinary observing chair, which is convenient enough when it is not more than sixteen feet high, becomes a cumbrous and inconvenient affair when it is extended to thirty-five feet. Mr. Grubb proposed to remedy this by raising the whole floor of the dome like an elevator to the proper height.

The details of this proposal were not worked out by Mr. Grubb, but by Mr. Dickie, the superintendent of the Union Iron Works, and Captain Floyd, the president of the Lick Trustees. They have completely solved the problem. The whole floor will be raised vertically a distance of sixteen and one-half feet by four hydraulic rams, and the ascent is made in four minutes with a perfectly parallel motion. The water supply for this purpose comes from the watershed of the dome itself. This flows into a reservoir on Huyghen's Peak and is pumped by a windmill into the reservoir on Copernicus, giving a head of 135 feet. This is more than sufficient to turn the dome and to elevate the floor; and the water, which is precious in this dry climate, is not wasted but used over and over. The last difficulty is now overcome, and it is expected that the steel dome will be mounted during the present year, or at least in the spring of 1887. The contract price for the dome delivered and erected is $56,800.

Signs of a purely astronomical activity are not wanting. The Lick trustees have engaged Mr. James E. Keeler, for a long time assistant to Professor Langley, as astronomer; and have invited Professor Comstock, formerly of the Washburn Observatory, and now professor of astronomy at the Ohio State University, to investigate the new meridian circle. In a few days the observatory will begin giving time-signals over the whole system of the railways from Ogden, Utah, to El Paso, Texas, as well as to the cities of San Jose and San Francisco. Everything is progressing rapidly and surely in this country, which is the paradise of builders, where the lower story is entered by the plasterers before the second story has its floor. Before the rains begin it is hoped to have all the important buildings completed and occupied. The brick work of the large dome is finished, and it only waits for its covering, looking now like the Coliseum at Rome. If there is no untoward accident, the observatory should enter into activity during the latter part of 1887. With faithfulness on the part of the company of astronomers to whom this magnificent equipment is confided, and with the support of the friends of science, much may be expected to follow from Mr. Lick's splendid gift to America and to the world.

EDWARD S. HOLDEN.

ENGINEERING.

Cost of Labor in Ceylon.

In an article on "Ceylon Government Railways," in *Engineering*, F. O'Driscoll gives an idea of the price of labor and excavation in that country. Labor averages 18 cents per man per day. Rock cutting on the Peradinia Junction cost, by contract, 75 cents per cubic yard. The earth cutting, which is in reddish-yellow conglomerate, cost 12½ cents per cubic yard to shift. **

The St. Lawrence Bridge.

The new St. Lawrence Bridge was the subject of a paper read recently by Mr. R. L. Harris before the Society of Civil Engineers, in which the great contrast was illustrated between old and modern methods of bridge building, as shown in the new structure and the Victoria Bridge a few miles below.

The following facts are culled from an abstract of the paper given in the *Railroad Gazette*: "The new bridge consists of fifteen spans, aggregating 3534½ feet, with tops of piers 30 feet above the ordinary stage of water. The foundations are rock. In all, some 4000 cubic yards of concrete and 7000 yards of bridge masonry have been built. The bridge is in a rapid current of 8 to 12 miles per hour, the greatest depth of water being 40 feet. The Lachine rapids are two miles below. Three steamboats were constantly employed during the construction of the masonry, and over four miles of chain cable and wire rope were used. The season for work on foundation is short, especially as there is an immense amount of running ice in the river after the weather has moderated in the spring. The contract was let on November 1st, 1885, requiring that all the masonry in the difficult location should be completed by the end of November, 1886, under a forfeit of $40,000. This exacting demand was fulfilled with eighteen days to spare. The superstructure is to be erected complete during 1886.

"The Victoria Bridge was in process of building from 1854 to 1859 inclusive, or six years. In the first season but one pier was erected; in the next season, but one more; at the end of the third season, only nine piers were built. The entire twenty-four piers were not completed until the end of the sixth season, although the greatest depth of water was only 22 feet and the current only 2 to 8 miles per hour. The total length of the bridge was 6592 feet, or about double that of the new bridge, while its cost was about $6,500,000, in contrast of the latter, which, if information is correct, is less than $1,000,000."

It is but just to add, that for the new bridge the rapid but questionable method of laying the concrete under water was adopted.

Forth Bridge.

In this connection some data regarding the celebrated Forth Bridge, now erecting in Scotland, will be interesting.

The total length is 8091 feet, and the estimated cost $8,000,000. The chief dimensions are:

Two main spans, each,		1710 feet.
Projection of cantilevers beyond pier,		680 "
Depth of truss of cantilever,		330 "
Extreme height of top of cantilever above high water,		354 "
Diameter of tubes forming bottom boom of cantilevers	at pier,	12 "
	at end,	5 "

Diameter of tubes forming main vertical posts of cantilevers, . .	12 feet.
Diameter of tubes forming diagonals to main posts (over piers), .	8 "
Centre girder span, ...	350 "
Centre girder, depth at centre, ...	50 "
Clear height of bridge above high water, ...	150 "
Approach viaduct span, ...	168 "
Weight of steel in superstructure, 94,080,000 pounds.	**

Working Stress on Rivets.

At a recent meeting of the American Society of Mechanical Engineers, a paper was presented by Mr. Benjamin Baker, now engaged in the construction of the Forth bridge, in which he gives interesting "notes upon the working stress of iron and steel."

"As regards riveted structures, it is of course the aim of both engineer and manufacturer to ensure every rivet gripping the plates with a stress fully up to the elastic limit. M. Considére, who has recently completed a most important and scientific series of experiments upon riveted joints, sums up thus: 'In all constructions in which the riveted portions have not already commenced sliding, the rivets work solely by longitudinal tension, and the resistance which this tension gives rise to between the plates in contact constitutes the sole resistance.' And further: 'any alternating stress in excess of that adherence rapidly dislocates the work.' The writer's experiments fully confirm these conclusions. At the Forth bridge the rivets in the heavy bed-plates are $1\frac{3}{16}$ inch diameter, and pass through 8 inches thickness of plates. Closed with hydraulic riveters of 40 tons pressure, the rivets, as a rule, fit the holes fairly; but care is taken that the stress is kept within the frictional adherence arising from the elastic grip of the rivets.

"With rivets of the same length as those in the bed-plates the average resistance to sliding was found to be equivalent to a shearing stress of 14,500 lbs. per square inch of rivet area, whilst the maximum adhering stress on any rivet in the bridge is limited to 11,200 lbs. per square inch. M. Considère found that with ordinary riveting he could reckon upon an adherence of 11,300 to 14,400 lbs. per square inch, which closely agrees with the former results.

"The writer, by testing plates in ordinary condition secured by bolts screwed up to a known tension, found that the coefficient of friction averaged one-third; and he also found that the soft steel rivet, after being closed up by hydraulic pressure, had an increased ultimate strength of 10 to 15 per cent., and an elastic limit of about 45,000 lbs. per square inch.

"Now, 45,000 lbs. $\times \frac{1}{3} = 15{,}000$ lbs., which was the ascertained resistance to sliding of the plate; and it is clearly demonstrated, therefore, that in sound work the rivets are permanently strained up to the elastic limit. This result was further confirmed by temperature experiments, measurements of contraction of rivets and other means which need not be detailed here." **

Mild Steel v. *Iron.*

Mr. Baker continues in the above mentioned article: "In concluding this paper the writer would like to bear testimony to the admirable behavior of a very good friend of his—mild steel. During the past three years he has had to deal with about 24,000 tons of that material, and to submit it in many cases to very hard treatment. He has had more cases of so-termed 'mysterious fractures' with the few tons of

wrought iron used for certain temporary purposes, than with the whole 24,000 tons of steel. This result of his experience may be of interest to brother members of this society who now are, or will doubtless be, large users of mild steel; and the testimony is perhaps of the greater value, as the work at the Forth is pressing on day and night, and no precautions are taken which would not equally be necessary were the material the highest class of Lowmoor iron, costing double or treble the price of the steel."

In a recent conversation with one of our most prominent bridge engineers, I alluded to this remark of Mr. Baker's concerning mild steel. "Ah," he remarked, "when Mr. Baker was in my office I felt strongly tempted to ask him what would have been the nature of his experience if he had used American iron for those temporary structures? The fact is, that the English iron is greatly inferior to ours, and if it were of equal quality we would hear less of the superior reliability of mild steel." **

Iron v. *Stone Bridges.*

Mr. Joseph M. Wilson, C. E., late engineer of bridges for the Penn. R. R., said in a discussion before the Am. Soc. of C. E. "The great point in favor of stone bridges, and really their saving clause, has been their great excess of strength.

"Those who favor stone bridges say: 'Oh, yes, they cost more money than iron bridges, but they are much more permanent.' I say, put the same excess of material in your iron bridges, or rather the same excess of cost, and you will have a structure much better adapted to resist travel, time and the elements, than you have in a stone bridge. I have never been in favor of stone bridges of any size for railroad traffic, particularly in our climate. The material, from its brittle, crumbling nature, is very ill adapted to resist the action of variable loads, impact, etc., and wherever frost can enter, it slowly, but surely, does its work. I have examined arch culverts over many miles of road; I have watched carefully over stone spans of considerable size, and have had to do with extensive repairs. I know that this is so, and the dilapidated condition of many, even large culverts on some of the roads, is a disgrace to them. It is fortunate that they are below and out of sight." **

Wooden Dams.

In the transactions of the American Society of Civil Engineers for August, 1886, is an exhaustive paper by Mr. Clemens Herschel on the work done for the preservation of the Holyoke dam, on the Connecticut River. "The lesson of 1849 to 1886 in the construction of wooden dams," as given by Mr. Herschel, deserves wide publication. He states: "Speaking of the lesson above cited as it presents itself to me, I should say:

First and foremost.—"That a wooden dam should never be left hollow, nor should it be filled with stone. Let a row of sheet piling be put in in some proper position, then puddle in gravel. Gravel is water-tight, or soon becomes so; stone filling is not. Gravel will protect every timber it encases from rot forever; stone filling will permit decay, and so will the moist, foul air to be found in the interior of all hollow dams. Worst of all is a dam entirely hollow.

Secondly.—"In crib work two timbers should never be butted on top

of another of the course next underneath. This would give each timber at the most a six-inch bearing, and should the lower timber become decayed at the edges, or the butting timbers at the ends (both being places where decay is worst), the strength of the bearing is speedily reduced to zero. It looks well on a drawing, or in new work, thus to butt timbers and the covering plank. But a great deal can be learned in pulling an old dam to pieces, and were I to design a new dam I should do neither.

Thirdly.—"Do not make a masonry shelf on each abutment to take the place of the last bent or frame of the dam. When the dam settles, or compresses under its load, as it must, the shelf does not follow, and the result is a distortion of the framing of several bents next to the abutments.

Fourthly.—"The back of the dam needs to be protected against the abuse of the dropping of four ton stones upon it, especially in the case of dams upon large rivers.

Fifthly.—"The shape of a dam should be chosen with a view to prevent the excavation of large masses of the river bed, and the formation of a pool below the dam, in all cases.

"It is absolutely necessary to do this in the case of a gravel bottom; it should never be neglected in the case of a soft rock bottom; it should be done in many cases of a granite or other hard ledge bottom. A pool of water that cannot be laid dry is a source of danger in all hydraulic works, for the reason that one can never be certain as to what may, or may not be taking place below the water surface; unless, indeed, periodical inspection be made in diver's armor, and even that would result in far less frequent examinations." **

CHEMISTRY.

The Volumetric Determination of Sulphuric Acid without Standard Solutions.

The gradimetric determination of sulphuric acid as barium sulphate is subject to many sources of error, which render the estimation far less trustworthy than it is popularly supposed to be. To eliminate these errors various volumetric methods have been employed, the latest of which we will briefly describe here.

When we add an alkaline sulphate to a hydrochloric solution of barium chromate in excess, we have the formation of barium sulphate and alkaline chromate. On neutralizing the mixture with ammonia the excess of barium chromate is precipitated, leaving in solution only that amount of chromic acid which has been replaced by the sulphuric acid added. By now diluting to a known volume, and filtering off a portion of the clear solution, and determining in it the amount of chromic acid, we will arrive directly at the amount equivalent to the sulphuric acid used. The author determines the amount of chromic acid by filtering with a ferrous salt, but it is evident that other methods could be employed, perhaps with advantage. The sulphate is compared with a known amount of potassic sulphate, and the relative volumes of iron solution used correspond to the relative amounts of sulphuric acid present; this obviates the necessity of standardizing any of the solutions. The results obtained are correct to within about one per cent. of the total sulphuric acid present. For fuller details we refer to the original paper. H. Quantin, *Moniteur Scientifique, Quesueville* (October, 1886, p. 1222), and *Chemical News* (November 5, 1886, p. 233). †

Geology and Mineralogy.

Ferruginous Schists and Iron Ores of the Lake Superior Region (*Am. Jour. Sci.*, III., Vol. xxxii., pp. 255–272).

After an extensive and detailed study of the deposits in question, Prof. Irving arrives at the following conclusions: "The original form of the beds of the iron-bearing horizons of the Lake Superior region was that of a series of thinly bedded carbonates, interstratified with carbonaceous shaly layers, which were also often impregnated by the same carbonate. This carbonate was generally more or less highly ferriferous, though probably there were intermediate forms between it and dolomite. With these unaltered layers there seems to have been some little magnetite in the shape of a fine dust mingled with the carbonaceous impurities, but most of the magnetite now found is taken to be secondary."

The varieties of ferruginous rocks occurring in the region were formed through the alteration of the "carbonate bearing layers," by the action of silicated solutions. The iron leached out by these agencies was reprecipitated from solution in various places to form ore bodies and impregnations, also yielding "the coloring matter of the jasper, the finely interlaminated hematite of which is taken to be mainly the result of a secondary infiltration following the banding of the original rock, though we may imagine the hematite bands to have formed at times by direct oxidation from iron carbonate seams."

In some cases "the silicifying waters seem to have decomposed the iron carbonate in place, producing a magnesia-silicate, or a magnesia-iron-silicate, the excess of iron oxidizing imperfectly and separating out as magnetite, and the excess of silica crystallizing finally as a minutely interlocked quartz ground mass. Thus have arisen most of the actinolitic magnetite schists. The various intermediate forms met with between the magnetic and jaspery or cherty hematitic schists may be explained by the carrying out simultaneously of the processes of removal of the carbonate and its decomposition in place."

A few of the bodies of red hematite are believed to have originated directly from the decomposition and oxidation of the carbonates *in loco*. The majority of them, however, as well as of the specular ores, Prof. Irving considers to have resulted from the precipitation of iron dissolved out of the carbonates. Some doubt is expressed as to the true origin of certain of the ore bodies, both specular and magnetic, owing, the investigator suspects, to lack of close acquaintance.

The evidence of the various layers indicates that the silicification was in part anterior and in part posterior to the disturbance of the beds by hypogene agencies. F. J. H. M.

The Genesis of the Diamond.

The first diamond found in South Africa was in 1867, when a large diamond was picked out of a lot of pebbles gathered in the Orange River. This led to the "river diggings" on the Orange Vaal rivers, which continue to the present time.

In 1870 the news came of the discovery of diamonds at a point some fifteen miles away from the river, where the town of Kimberley now

stands. These were the so-called "dry-diggings," at first thought to be alluvial deposits, but now proved to be volcanic pipes of a highly interesting character. Four of these pipes or necks, all rich in diamonds and of similar geological structure, were found close together. They have been proved to go down vertically to an unknown depth penetrating the surrounding strata.

The diamond-bearing material at first excavated was a crumbling yellowish earth, which at a depth of about fifty feet became harder and darker, finally acquiring a slaty blue or dark green color and a greasy feel, resembling certain varieties of serpentine. This is the well-known "blue ground" of the diamond miners.

It is exposed to the sun for a short time when it readily disintegrates and is then washed for its diamonds. This blue ground has now been penetrated to a depth of six hundred feet and is found to become harder and more rock-like as the depth increases.

Quite recently, both in the Kimberley and DeBeers mines, the remarkable rock has been reached which forms the subject of the present paper.

As Griesbach, Stow, Shaw, Rupert Jones and others have shown, the diamond-bearing pipes penetrate strata of carboniferous and triassic age, the latter being known as the Karoo formation.

The Karoo beds contain numerous interstratified sheets of dolerite and melaphyr, also of triassic age, the whole reposing upon ancient mica schists and granites. The careful investigations of Mr. E. J. Dunn demonstrate that the diamond-bearing pipes enclose fragments of all these rocks, which fragments show signs of alteration by heat. Where the pipes adjoin the Karoo shales the latter are bent sharply upwards and the evidence is complete that the diamond-bearing rock is of volcanic origin and of post triassic age.

The diamonds in each of the four pipes have distinctive characters of their own and are remarkable for the sharpness of their crystalline form (octahedrons and dodecahedrons), and for the absence of any signs of attrition. These facts, taken in connection with the character of the blue ground, indicate, as Mr. Dunn has pointed out, that the latter is the original matrix of the diamond.

Maskelyne and Flight have studied the microscopical and chemical characters of the blue ground and have shown that it is a serpentinic substance containing bronzite, ilmenite, garnet, diallage and vaalite (an altered mica), and is probably an altered igneous rock, the decomposed character of the material examined preventing exact determination of its nature. They showed that the diamonds were marked by etch figures analogous to those which Professor Gustav Rose had produced by the incipient combustion of diamonds and that the blue ground was essentially a silicate of magnesium impregnated with carbonates.

The blue ground often contains such numerous fragments of carbonaceous shale as to resemble a breccia. Recent excavations have shown that large quantities of this shale surround the mines, and that they are so highly carbonaceous as to be combustible, smouldering for long periods when accidentally fired. Mr. Paterson states that it is at the outer portions of the pipes where the blue ground is most heavily charged with carbonaceous shale that there is the richest yield of diamonds.

Mr. Dunn regards the blue ground as a decomposed gabbro, while Mr. Hudleston, Mr. Rupert Jones, and Mr. Davies regard it as a sort of volcanic mud. Mr. Hudleston considers that the action was hydrothermal rather than igneous, the diamonds being the result of the contact of steam and magnesian mud under pressure upon the carbonaceous shales, and likens the rock to a "boiled plum pudding."

The earlier theories as to the origin of the diamond have, in the light of new facts, quite given way to the theory that the diamonds were formed in the matrix in which they lie, and that the matrix is in some way of volcanic origin, either in the form of mud, ashes, or lava.

The exact nature of this matrix becomes, therefore a matter of great interest. The rocks now to be described are from the deeper portions of the DeBeers mine. They are quite fresh, and less decomposed than any previously examined. Two varieties occur,—the one a diamantiferous, the other free from diamonds,—and the lithological distinction between them is suggestive. The diamantiferous variety is crowded with included fragments of carbonaceous shale, while the non-diamantiferous variety is apparently free from all inclusions, and is a typical volcanic rock.

Both are dark, heavy basic rocks, composed essentially of olivine, and belong to the group of peridotites. Both are of similar structure and composition, differing only in the presence or absence of inclusions. The rock consists mainly of olivine crystals lying porphyritically in a serpentinic ground mass.

The olivine is remarkably fresh and occurs in crystals which are generally rounded by subsequent corrosion. The principal accessory minerals are biotite and enstatite. The biotite is in crystals, often more or less rounded and sometimes surrounded by a thin black rim, due to corrosion. Similar black rims surround biotite in many basalts. The biotite crystals are usually twinned according to the base. The enstatite is clear and non-pleochroic. Garnet and ilmenite also occur, the latter often partly altered to leucoxene. All these minerals lie in the serpentinic base, originally olivine. This rock appears to differ from any heretofore known, and may be described as a saxonite porphyry.

The diamond-bearing portions often contain so many inclusions of shale as to resemble a breccia, and thus the lava passes by degrees into tuff or volcanic ash, which is also rich in diamonds and is more readily decomposable than the denser lava.

It seems evident that the diamond-bearing pipes are true volcanic necks, composed of a very basic lava associated with a volcanic breccia and with tuff, and that the diamonds are secondary minerals produced by the reaction of this lava, with heat and pressure, on the carbonaceous shales in contact with and enveloped by it.

The researches of Zirkel, Bonney, Judd, and others have brought to light many eruptive peridotites, and Baubree has produced artificially one variety (lherzolite) by dry fusion, but this appears to be the first clear case of a peridotite volcano with peridotite ash.

Perhaps an analogous case is in Elliot county, Kentucky, where Mr. J. S. Diller has recently described an eruptive peridotite which contains the same accessory minerals as the peridotite of Kimberley, and also penetrates and encloses fragments of carboniferous shale, thus suggesting interesting possibilities.—H. CARVILL LEWIS, in *Science*.

RUBBER BELTING, PACKING, HOSE,

RUBBER TUBING, RUBBER MATS,

MATTING, and STAIR TREADS.

All kinds of Rubber Goods for Mechanical Purposes.

DIAPHRAGMS, GASKETS and RINGS, ROLLS, STOPPLES, VALVES and TUBING—BLACK or WHITE, for GAS, WATER, and INSULATING RUBBER BAGS.

Largest Manufacturers in the U. S.

New York Belting and Packing Co.,

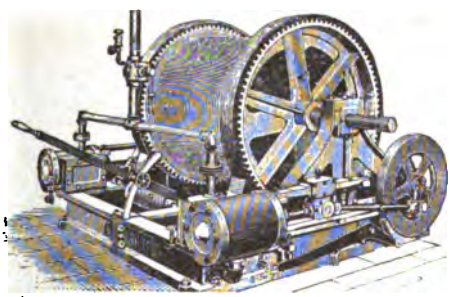
15 PARK ROW (Opposite Post Office), **NEW YORK.**

JOHN H. CHEEVER, TREASURER.

Improved Hoisting Engines

WITH

Wire-Rope Drums and Safety Brakes.



Specially adapted to Mining Interests.

ALSO COMBINED

Engines and Boilers, and Horizontal Stationary Engines.

LIDGERWOOD MFG. CO., 96 Liberty St., N. Y.

NEW CATALOGUES NOW READY.

SCHOOL OF MINES QUARTERLY.

VOL. VIII., 1886-87.

EDITORS.—J. K. Rees, J. B. Mackintosh, A. J. Moses, J. L. Greenleaf, E. A. Congdon, H. Parsons.

J. L. Greenleaf, *Managing Editor;* A. J. Moses, *Business Manager.*

ASSOCIATE EDITORS.—F. A. P. Barnard, J. S. Newberry, T. Egleston, W. P. Trowbridge, H. S. Munroe, F. R. Hutton, Elwyn Waller, P. de P. Ricketts, M. W. Iles, R. D. Irving, H. B. Cornwall, P. T. Austen, C. M. Rolker, J. A. Church, W. B. Potter S. A. Reed, W. B. Devereux, J. M. Adams, H. M. Wilson, J. C. F. Randolph.

Subscription price two dollars per annum, or fifty cents per number.

NOTICE TO GRADUATES.—The Quarterly will print in the July number a complete list of all graduates of the School of Mines, compiled from the records of the Secretary of the Alumni Society. It is requested that the Editors be notified of any changes by filling out the blank on next page and mailing it to

THE SCHOOL OF MINES QUARTERLY, New York City.

FIELD, ROBERT P.,
CONSULTING,
Mining and Civil Engineer.
Coal Mining and Coking a Specialty.
148 S. Fourth Street, Philada., Pa.
Box 1228.

OLCOTT, EBEN E., E.M.,
MINING ENGINEER
AND
METALLURGIST,
10 Cedar Street, New York City
Cable address, "Kramolena."
Examines and reports on mines or metallurgical establishments
Has had considerable experience in Gold and Silver Mines in South America and Mexico.
Eastern representative of the M. P. Boss Continuous Milling System.

LEDOUX & COMPANY,
Consulting Engineers and Metallurgists,
10 Cedar Street, New York.
Complete Sample Works and Laboratories. Assaying, Sampling, Concentrating and Milling small or large lots of ANY ORE. NEW PROCESSES and NEW MACHINES tried, and their PRACTICAL VALUE determined.
Mineral and Commercial Analyses of all kinds,
☞ Special terms and inducements offered to professional men, including School of Mines Alumni.

PISTOR, WILLIAM,
ARCHITECT,
No. 35 Broad St.,
NEW YORK.

MAYNARD, GEO. W.,
Mining and Metallurgical
ENGINEER.
Designs for Mining, Dressing, and Metallurgical Plants.
OFFICE, 86 BROADWAY, NEW YORK.

RANDOLPH, JOHN C. F.,
Consulting Mining Engineer,
86 Broadway, - - NEW YORK.
Examines and reports on mines.
Extensive experience in all parts of the world.
Cable address, "RHOSGOG," New York.

THE

SCHOOL OF MINES QUARTERLY.

VOL. VIII. APRIL, 1887. No. 3.

SUB-SURFACE WATER SUPPLIES.

BY PROFESSOR W. P. TROWBRIDGE.

Two or three years ago, I prepared a paper for the *Sanitary Engineer*, describing the driven wells, and the method of connecting them with pumps, by which a large supply of pure water had been obtained for the city of Brooklyn from the gravel deposits on Long Island. The simplicity of the means adopted and the large and constant volume of water obtained were alluded to as constituting a new and successful experiment on a large scale in connection with the supply of water to towns.

Since the publication of the paper referred to, the Messrs. Andrews & Co., contractors, have established two additional "plants" along the line of the Brooklyn Aqueduct, increasing the supply for the city to eighteen millions of gallons daily from this source alone,—a quantity equal to one-sixth of the supply to the city of New York at the present time.

This large volume of water is obtained from four hundred and sixty (460) 2-inch tubes (equivalent in area of cross section to a single tube or pipe 44 inches diameter) driven from forty to seventy feet into the gravel deposits. On a trial-test, these tubes have furnished twenty-seven millions of gallons in twenty-four hours. Eighteen millions is not, therefore, the maximum supplying capacity of these wells at this time.

It is not contended that there is anything novel in the idea of

obtaining water for any purpose from the unconsolidated or loose detritus of the earth's surface; but the means and appliances, by which such large quantities are drawn continuously and permanently from a few tubes driven into the ground, are so effective and simple, and so much has been done to encourage further operations of the same kind, and to throw light upon the characteristics of these underground water-bearing deposits that it may be said that new resources, in connection with the water supply of the largest towns, have been opened to the engineer—resources not *always* available, it is true, but in many cases highly practicable and economical.

The engineer who seeks a source from which may be obtained a proper supply of water for a town, must take into consideration a great variety of circumstances. Among these, the meteorological and geological conditions which prevail in the district are most important, since these influence the quantity as the well as the quality of the water obtained. Of all meteorological agencies, there are none which have more controlling influence on the physical geography of the globe and the adaptation of any part of its surface to the necessities of the human race than those which relate to rainfall and the reflux of the condensed waters to the sea. The causes which determine the quantity of rain which falls in any region are various; ocean currents, aerial currents, mountain ranges, extended valleys and plains,—all produce their effects; and, although the most varied extremes occur of regions where vegetation is luxuriant on the one hand, and where deserts exist without rainfall on the other, yet such is the constancy of nature in her great cycle of changes, that each place receives its appointed share almost unchanged from year to year.

The average rainfall of a region is, therefore, in most civilized countries, one of the best established of all meteorological phenomena.

It is not so, however, in regard to the return of the waters to the sea. The flow of surface streams may, it is true, be determined with approximate accuracy, and their courses are well defined; but the disposal by nature of that large part of the rain which does not appear in the rivers and brooks, as they accumulate in magnitude towards the sea, is involved in much obscurity. A portion of the condensed vapors is known to be absorbed by plants, and a portion is reëvaporated, but a still greater part, appa-

rently, disappears beneath the earth's surface. By what precise channels this large volume of water ultimately reaches the ocean, how much of it enters the covered out-crops of porous strata and finding its way deep into the earth's crust between underlying and overlying consolidated beds, is ultimately discharged underneath the waters of the ocean; how much enters faults and fissures, and again issues in springs of pure or mineral waters; how much is concerned in excavating underground courses through or among the softer or more soluble rocks, or follows channels already thus excavated, is not and cannot be known. But that no inconsiderable portion of this subterranean flow follows more shallow channels in the loose detritus upon the surface seems probable. In most countries where the rainfall is copious, moderate excavations at the surface reveal the presence of water. In our own country every farm has its well, whether it be situated on a hill or in a valley; and, while these wells occasionally become dry in very dry years, it is apparently, in most cases, because they have not been sunk deep enough to reach those water-bearing beds of gravel and sand from which a perpetual and continuous supply might be obtained. The farmer, in sinking a well, looks gratefully for the first indication of water, and as his needs are not excessive, the sinking of the well is stopped when the upper surface of the first water-bearing stratum is reached. The methods and appliances at his command do not permit him to sink deep into watery ground.

The "driven well" goes deeper, and the tube is easily driven through soft ground to any desired depth; while the artesian boring proper pierces the solid strata still lower, if necessary, and draws its waters from sources more distant than those which supply the common or the driven well.

The proportion of the rainfall which passes off by the surface streams is so variable in different places, that actual gaugings of the streams is generally necessary to determine it. Over a large portion of our Northern States, this proportion is from 30 per cent. to 90 per cent. of the rainfall, depending upon the seasons, the surface topography, and the geological characteristics of a district. From 10 per cent. to 70 per cent. of the rainfall for the same localities disappears, being absorbed by plants, reëvaporated from the surface, or sinks beneath it, and of this latter portion there is no

doubt that, in many parts of our country, nearly all follows shallow sub-surface channels slowly to the sea-levels.

Artesian wells have become so common in every quarter of the globe as to no longer excite especial interest, beyond that which may be attached to the great depths of some and the large volume of flow from others. As a general rule the hard or consolidated strata of the earth's crust have to be pierced, often at very great depths, to reach water-bearing strata which have been pointed out by precise geological knowledge, or which are sought for with much expense and uncertainty where such knowledge is wanting.

While the mechanical processes of boring these wells have reached such a degree of excellence and certainty that individuals or companies may now be found ready to undertake for a specified sum per foot the sinking of an artesian well to any reasonable depth, yet the great cost and the uncertainty of success, of any one boring as regards the volume of water which may be permanently obtained, causes this method of search for water to be adopted for cities and towns only as a last resort.

If it be proper to classify the systems which have been referred to as the "artesian" and the "driven well" systems, it can be said of the latter that the methods of exploration and well-sinking which have been recently developed seem to offer incontestable advantages, and to promise results of the greatest value and importance. Facts have been established, in the explorations already made in different places, which seem to offer strong inducements for further and systematic researches, not only from an economic but from a scientific point of view. Among the scientific questions presented, those which appear to be of special interest relate to the causes of some of the peculiar phenomena of deposition and arrangement presented in the interstratified beds of gravel, clay, and sand which are found to exist; and, if these are connected in any way with ancient river beds, the possibility of tracing out these beds with greater certainty.

A study of these surface deposits by the methods which have been introduced for the driven wells, and which is attended with little difficulty and expense, comparatively, seems to offer, at least, an attractive field for economic and scientific explorations.

Through the kindness of Mr. W. D. Andrews I have obtained sketches which illustrate the construction of one of the four "plants" on Long Island from which the supply above mentioned

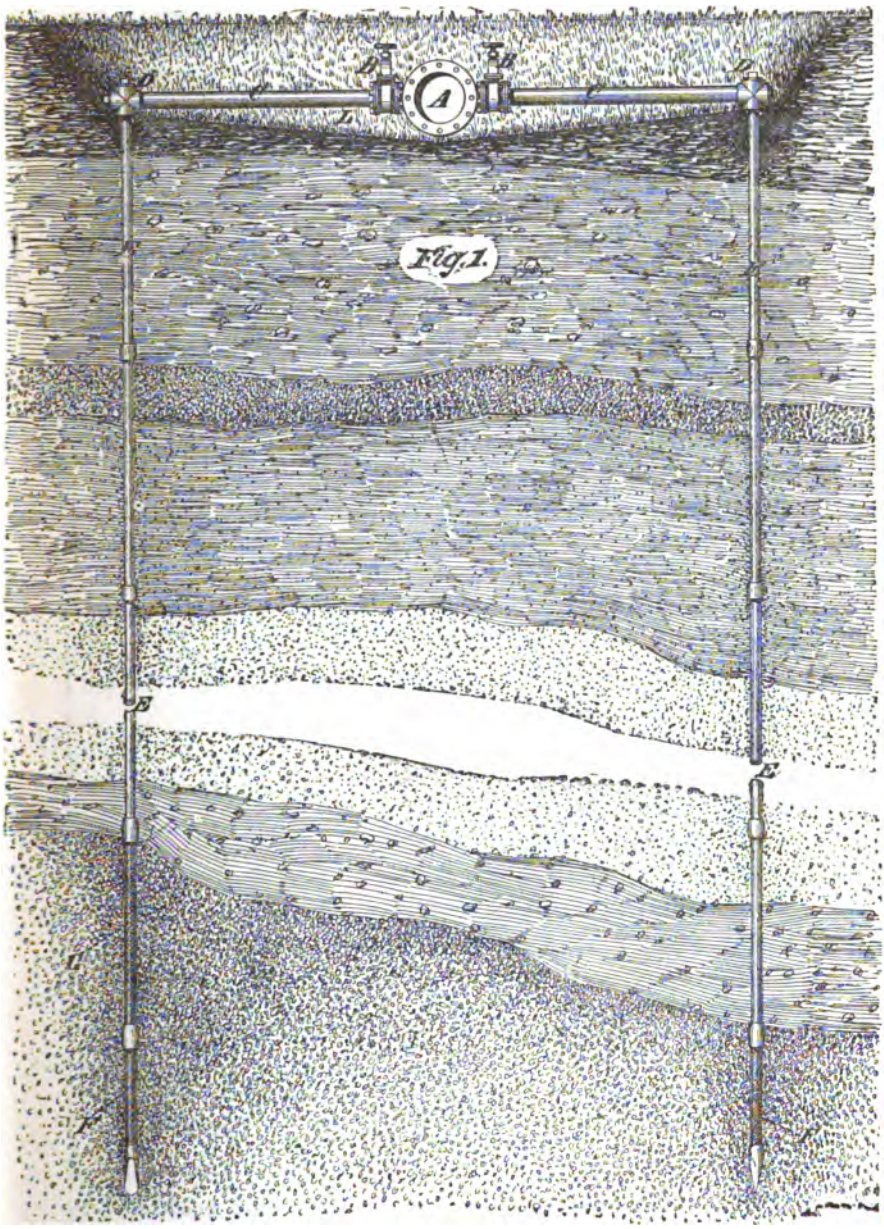
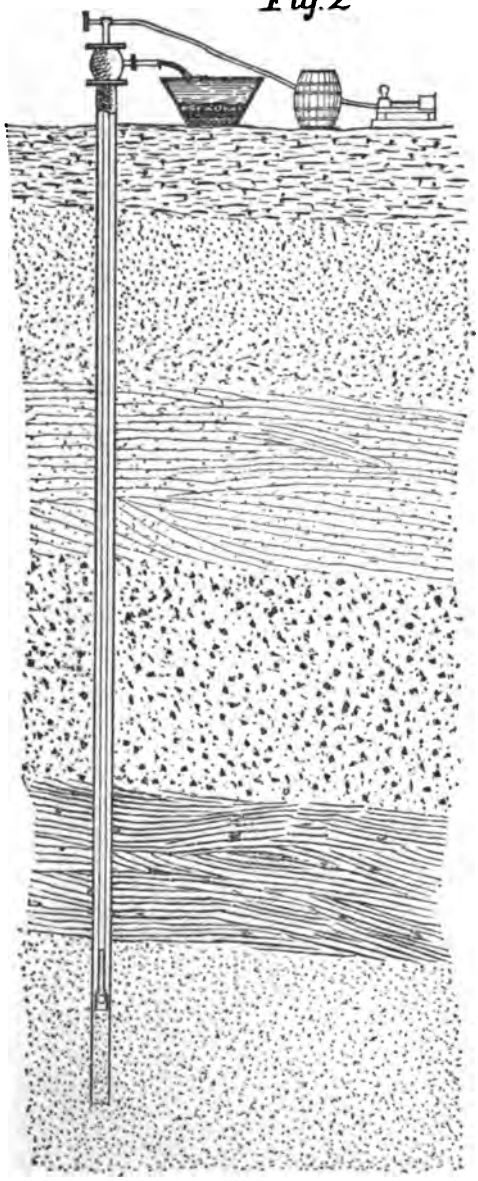
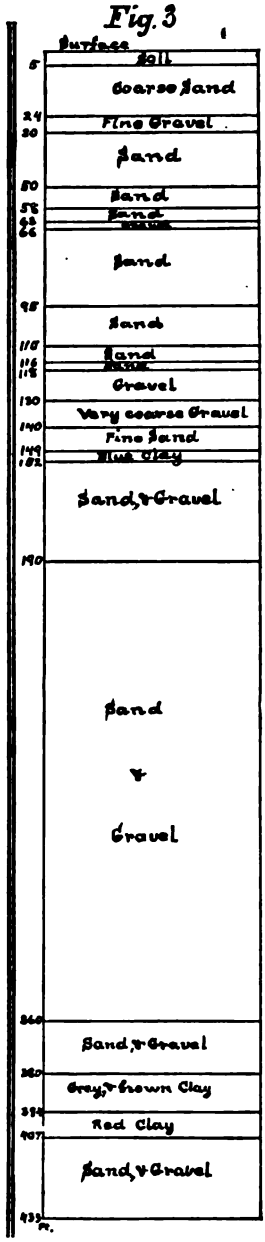

A
Fig. 1.

Fig. 2



Sketch showing apparatus for prospecting for water.

Fig. 3



Section of deposits on Long Island in the vicinity of the driven wells.

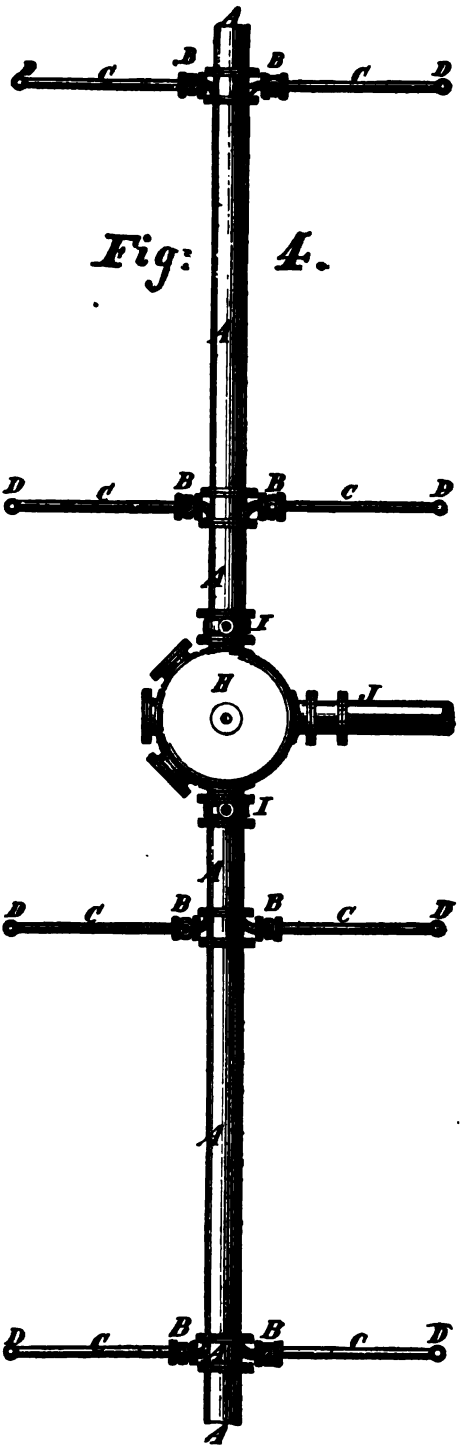


Fig: 4.

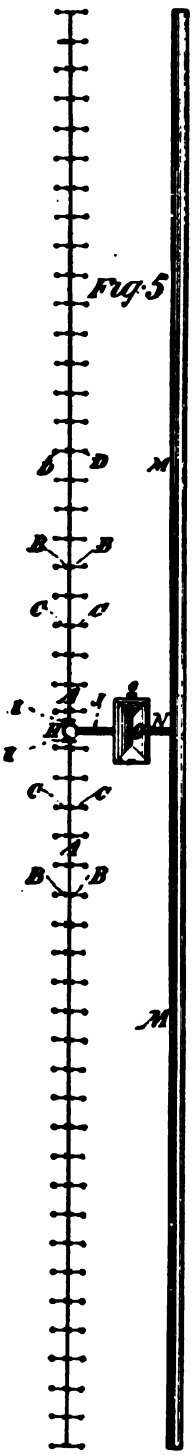


Fig: 5

is obtained, and also a sketch illustrating the process of boring or prospecting adopted; and another representing a section of the deposits of sand, gravel, and clay in the vicinity of one of these plants to the depth of 433 feet.

In these sketches Fig. 5, represents a plan of the whole "plant." The system of driven tubes occupies a space about 800 feet long and 15 feet broad, parallel with the line of the Brooklyn aqueduct. The tubes are in two rows about 15 feet apart, while in each line the tubes are about 12 feet apart. Fig. 5, shows the relative position of the Brooklyn aqueduct, M, the pump house, O, and the driven wells in two rows DD, Fig. 4. Fig. 4, is an enlarged view of a portion of the plan. In this sketch it will be seen that each tube is connected with a large pipe A, lying midway between the two rows of driven tubes and connecting them with a central or common chamber H, from which the suction pipe J extends to the pump house. In this Fig. the connecting pipes C C, and the junction B B are shown more clearly than in Fig. 5.

The pumps in the pump house O draw water from all the wells simultaneously and discharge it directly into the aqueduct through the pipe N. (Fig. 5).

Fig. 1 represents a vertical section through two driven wells, showing the extension of the tubes downward through several strata of sand and gravel to the lower stratum G, from which the supply is drawn. The ends of the tubes are pointed to facilitate them being pushed downwards, and are perforated for several feet in length near the ends to permit the entrance of the water. The perforations being covered with a wire netting to prevent the introduction of large pieces of gravel.

Fig. 2 illustrates the apparatus for prospecting for water. A two inch tube is driven down for a few feet at the surface with fittings at the top which close the top except that a spout shown in the figure is attached to discharge water, sand, gravel and clay into a tub. These fittings permit of a smaller tube being inserted into the top of the larger with a hollow handle connected with a flexible hose to a portable pump. A man by grasping this hollow handle can churn the inner tube up and down while water is being forced into it from the pump. The bottom of this inner tube is chisel-shaped, but there are two openings near the bottom which permits the water pumped through the inner tube to enter the space between the inner and outer tubes near the bottom. The churn-

ing action cuts up the sand and gravel, and as it is mingled with the water forced in, both the water and sand or clay are forced to the surface upwards between the two tubes and discharged into the tub.

A barrel or portable tank supplies the water if necessary. The specimens discharged into the tub are collected and preserved and thus a complete section of the strata may be obtained. The tubes may be extended by adding sections at the top as the boring extends downwards. Fig. 3 shows the section obtained near one of the plants on Long Island to the depth of 433 feet. Two of the gravel deposits passed through were composed of coarse rounded gravel, almost wholly free from any admixture of fine sand or clay, an evidence that there is a continued flow of water among the particles of gravel.

Mr. Henry E. Knox, Jr., formerly a student in the School of Mines, has been for many years engaged under the direction of the Messrs. Andrews in prospecting for water in various places, and I am indebted to him for the description of the prospecting device just described.

Mr. Knox found, between Albany and Troy, an extensive bed of gravel beneath a bed of fine clay, from 16 to 25 feet thick near the surface. The gravel bed is from 17 to 35 feet thick, about 700 feet wide, and of indefinite length, it having been traced about half a mile longitudinally.

The gravel from this bed is entirely different from that on Long Island. It is composed of coarser grains or fragments of dark-colored rock, nearly all of uniform size, and less rounded than those from Long Island, showing evidence of that kind of attrition which comes from running water rather than wave action.

Mr. Knox found precisely the same gravel in his explorations near Utica; and under a bed of clay, 118 feet thick, near Albany, he found a bed of clean gravel, of nearly uniform size and uniform material, but composed of angular, water-worn pebbles as large as pigeons' eggs.

One of the most important questions connected with the system adopted on Long Island, and which has been repeated elsewhere on a smaller scale, was the permanence of the full supplying capacity of the wells.

It was urged by some distinguished engineers that the tubes

must tap sheets or reservoirs of still water, and that a continued draught upon the system must speedily exhaust the reservoirs.

Experience has not confirmed this view. Mr. Knox informs me that, of the fifteen hundred or two thousand wells selected and driven by himself, not more than two or three have ceased to act, and that in nearly all the supply remains undiminished.

Experiments were made on Long Island to determine the line of depression of the water-level in the ground immediately adjacent to the plant of one hundred wells, while the pumps were drawing to their full capacity.

Test wells were sunk just outside of the plant on four sides, and a line of test wells extended out to a distance of 4000 feet from the pump-house. Observations were made during three months. At the distance of 4300 feet, the water-level was reduced about 6 inches. At a distance of 2300 feet, about 2′ 2″ inches, and in the immediate proximity to the wells, within a distance of 300 feet, the depression was 4′ 8″ feet. When the pumps were stopped, all the levels were restored.

The rate of flow to wells sunk in sand or gravel depends, of course, upon the compactness of the material of the water-bearing stratum, the resistance to the flow being proportional to the narrowness of the minute channels through which the water must flow, and to the number of windings and turnings which a particle is forced to take throughout its course to the pumps. The velocity of a particle of water running into an ordinary filtering gallery along the margin of a stream is generally less than one foot an hour. The velocity of a particle flowing towards the pumps in the driven-well plant on Long Island, taken a little outside the rectangle formed by the hundred wells, is about the same—a velocity too small to be directly perceptible to the eye. This small velocity shows what great relative resistances are encountered.

The form of the water-surface will, therefore, depend almost entirely upon the coarseness or compactness of the materials through which the water passes, and is not to be taken as a measure of the degree of exhaustion of the source of supply.

In all the explorations thus far made, it has been found that the gravel-beds, available for water, are not continuous over indefinite areas, nor of uniform thickness, but certain beds and particular channels in certain beds appear to constitute the underground water-ways, rendering systematic explorations necessary.

The questions which naturally arise, concerning these deposits, are: What have been the causes of the peculiar arrangements of sand, gravel and clay? Are the gravel deposits the beds of ancient water courses, along which the finer sands and clays have been washed away by the streams? Can these old river beds, if they exist, be traced and identified throughout their courses?

In the exploration between Albany and Troy, the appearance of the gravel found seems to indicate a common origin with that at Utica, and it is the opinion of Mr. Knox, that the same beds extend along the valley of the Mohawk between these points, but by a route not identical with the present course of that river.

The mode of exploration which has been described, renders it more simple and less expensive than might be imagined to conduct such researches, although not probably within the resources of private explorers.

An instance has recently come to my knowledge which adds new interest to this subject, inasmuch as in this case water was procured in abundance from a sub-surface deposit in loose material in a region where the small rainfall and the absence of permanent surface streams has heretofore been considered a serious obstacle to any permanent settlement of the region.

Mr. Arthur Macy, a graduate of the School of Mines, having been appointed to take charge of the famous "Silver King" mine in southwestern Arizona, found that for the extensive milling operations that would be necessary in the treatment of the ore, an amount of water would be necessary for which no adequate supply appeared available. A valley of several miles in extent lay above the mines and from the appearance of the country, he concluded that this valley, from which flowed a small torrent in the rainy season, must contain sub-surface water. He excavated two open wells, one 15 feet and the other 25 feet deep, at the outlet of the valley, and about 300 feet above his mills in vertical elevations and 3 miles distant from the mills.

A 3-inch pipe was carried from the mills up the valley to the wells, where it was connected to two syphons, one from each well; through these syphons, without the use of pumps, he obtains a continuous supply throughout the year of 200,000 gallons per day.

There is no doubt that Mr. Macy has thus discovered a practicable method of obtaining water in Arizona, which may be repeated in many parts of that territory and which will be found applicable in

many other regions heretofore supposed to be practically deprived of water.

There is now at least, abundant experience to encourage the search for and use of subterranean water for the most important uses of life in the shallow and loosely compacted deposits which cover plains and valleys. Another significant example is found in the new water-supply for the villages on the east shore of Staten Island. A large part of this island is known to be covered with drift. That portion which is embraced between the principal ridge of serpentine rocks running through the middle of the Island from north to south, and the dyke of basaltic rock which skirts the western shore of the island, both of which have been described by Mr. Britton before the New York Academy of Sciences, is especially to be noted as bearing water; a very large part of the rainfall, doubtless, because the whole area of eight or ten square miles is peculiarly devoid of surface streams.

Along the southwestern shore of the island there are unmistakable indications that the underground flow reaches the surface only a few feet above high water mark. Here the Crystal Water Co. have sunk large tubes about 40 feet into the drift. From these tubes the water destined for the village along the eastern shore of the Island is pumped to a reservoir, 3½ miles distant, situated on the top of the dividing ridge referred to, whence it descends through pipes by gravity about 2½ miles further to the eastern shore, furnishing a head of about 250 feet.

A few years ago Staten Island and Long Island were supposed to be almost destitute of water when the prospective wants of their large and increasing population were considered. Now it may be said, that in this respect, though isolated from the main land, they are better off in many respects than New York City. I recently examined at the request of the Trustees of the village of Edgewater, the facilities presented on Staten Island, and had no hesitation in advising that a contract might be safely made with the Crystal Water Co. for all the water which would probably be needed for a long term of years. Such a contract has since been made and the water supply for the towns referred to may be considered assured.

Perhaps my own interest in this subject is derived partially from some of the earlier associations of my life. In the State of Michigan where I passed my boyhood there is a tract of country 20 or 30

miles broad, bordering on the river and Lake St. Clair, the Detroit River, and Lake Erie, which is low and heavily wooded, and in wet seasons almost swampy. The settlers of this region had little difficulty in finding water a few feet below the surface, but there were few surface streams, and I have known the farmers to be obliged in very dry seasons to drive their stock several miles daily to water. A belt of country north of this and stretching from Lake Huron in a southwest direction quite across the State to Lake Michigan is covered with the most beautiful little lakes of pure and sparkling water. Lakes which never become stagnant and never dry up.

Farther north again toward the northern part of the State, are found extensive pine barrens, where again there are but few rivers and streams; but I have seen wells driven there from 6 to 10 feet only to an abundant supply of water. The little lakes I have referred to are replenished from the exposed outcroppings of gravel beds, and while they are often linked together so as to constitute the sources of considerable streams, the water from most of these lakes seems to sink away slowly again and to flow underground in broad sheets toward the great lakes. Nearly everywhere in this State water in abundance can be found by driven wells, and I am told that in the regions where the early settlers suffered so much from swamps and mud in winter, and drought in summer, surface drains and tube-wells have created an entirely new condition of things favorable to the farmer.

An objection has been frequently urged against the use of water from these shallow sub-surface deposits that there is danger from pollution or contamination of the water by sewage and surface drainage, the drainage from cemeteries, etc.

While it would obviously be undesirable to establish a driven well plant within the limits of a populous city it may be said that the necessity for so doing is never likely to occur. Moreover, the purifying influence of the soil by infiltration is known to be very effective; the well-known processes of sewage disposal by irrigation and downward filtration are based upon this property of the ordinary porous soils.

A microscopic analysis of the effluent water from the irrigation fields of Paris showed that the number of microbes in the sewage was reduced from 20,000 per cubic centimetre to 12 per cubic centimetre, and that the effluent water from the irrigation fields con-

tained fewer microbes than the water supplied to Paris for domestic uses. (See Gray's Report to the City Council of Providence.)

The water being drawn from considerable depths, usually, the purifying effect of the slow downward filtration from the surface would probably be much more complete than is produced by any artificial filtration.

It should be a source of public congratulation that while our rivers and streams must become polluted by a growing population nature furnishes another source of water-supply so abundant and widespread, so pure and so easily procurable.

Explorations and investigations having in view the more thorough study of this underground water-supply deserve, and should receive at the hands of the public, the most earnest appreciation and encouragement.

DRIFT-MINING.

BY T. EGLESTON, PH. D.

WHEN the auriferous gravels contained in the ancient river-channels are covered over to any great depth by the volcanic eruptions of past geological periods, or where the pay-gravel is concentrated in a layer, from 2 to 8 feet thick, directly on the bed-rock under a very thick deposit of either barren or very poor gravel which could not be profitably mined by the hydraulic process, or where, from scarcity of water or difficulty of getting dump room, owing to lack of fall of the ground below the mine, it would be impracticable to move the whole of a deep placer deposit, the gravel is mined and the method of working adopted is called drifting, and the claims are called drift-claims. The volcanic rock or gravel above the gold deposit cannot be moved, and the ancient channels, if reached at all, must be reached by tunnels run through the side of the rim-rock at sufficient depth to reach the deposit and make it possible to take out the pay in the ancient channel. Drifting is never done where hydraulicking is possible. It has come into notice more recently on hydraulic claims since the débris litigation, but would never be

practiced where it is possible to get rid of the whole of the ground.

When the great lava overflow of the Pliocene period swept over the surface of the country, it covered it to many hundred and sometimes fully a thousand feet deep. This lava-flow necessarily filled in the deep channel depressions, and there was enough besides to cover nearly all the elevations as well. The present streams, such as the Feather, Yuba and the American rivers, with their forks and branches, have gradually eroded great cañons in this volcanic flow, in which they now run 1000, 2000 and 3000 feet below the summit of the lava-capped hills. Their general course, more particularly in the region of the lava-covered river channels, is westerly. The erosion first cut away the lava, then the gravel, and finally cut down into the hard slates. This erosion was the principal cause of the formation of the gold-producing river beds and bars which were so extensively worked in the early days of California mining. The discovery of these deep leads is probably owing to the fact that certain miners, being unable to obtain possession of either the placer, river or bar claims, worked away upon the hill sides until they were led underneath the surface of the ground, which they followed into as far as their limited means would allow.

The deposits adapted to drifting are very extensive in California, but their development will take place slowly, as it takes time to explore them and capital to open them up. As a general thing, as they work in the dark, it requires more intelligence to make the preliminary surveys than in any other kind of gold mining. They do not invite speculation on account of the great risk which it is necessary to run in the first opening of the mine. The experience is general that they can be worked to best advantage by associations of companies of practical miners. All the great successes have been achieved by companies of this kind. The gold product from this source is estimated at between $3,000,000 and $4,000,000 a year, but it will undoubtedly be greatly increased in a few years.

Drift-mining is a permanent industry of Placer County, and is extensively carried on in Sierra and Plumas counties, and on a small scale in El Dorado County. The gravel is not always found in exactly the same condition. Some of it is ordinary gravel, easily mined with the pick and the shovel. Other gravels are hard but do not require blasting, and others are so hard and tough as

to require to be blasted in the mine and afterwards to be crushed in stamp mills before the gold can be extracted. Such gravels are called cement, and the mills are called cement mills.

It is a matter requiring the greatest judgment of the engineer to settle what it is advisable to do, to successfully open a given piece of ground which he is examining. The probable width of the channel can only be guessed at. Its depth can be ascertained by prospecting. As a general rule, it must be said that a knowledge of the known channels which have been worked out in a given locality is the best guide to work on. Long experience has shown that the highest slope of a channel will not usually exceed 30 degrees. They vary from 40 to 50 feet up to several hundred in width. They will average about 250 feet, but as a general thing will not exceed 600 to 700 feet in width.

The method of drifting was formerly employed to a small extent to work the bars on the rivers, which, as they are loose, were easily mined, but they had to be worked on a small scale, as there was but little material to work upon. The idea was to follow the pay leads under the banks, supporting the excavations by boulders, and working for short distances only, leaving holes rather than drifts, which soon caved. This method, which could not be worked on any system, was called "Coyotting." Drifting did not become a branch of mining until 1852 or 1853, about the time when the old river channels were discovered. Entirely underrating the difficulty of following them, shafts, inclines, and adits were sunken in every direction in the old channels of Sierra, Nevada, Placer, and Tuolumne counties, the large majority of which brought only failure to individuals and discredit on this method of mining. In the early stages of its history, many mistakes were made, which were very disastrous, owing for the most part to the tunnels having been run too high up to open the whole of the ground. Coyotting is not a method of mining, and was never known to capital. The enterprises were undertaken by the miners themselves, who either worked alone or in associations, the day's work being counted as so much invested capital. The methods of exploring ground, to determine the position and depth of the channel, were unknown. No shafts were sunk, the pay streak was followed were it was found. When the company had a number of members they worked until he money gave out, and when it was gone they worked as day aborers somewhere else

until money enough had been accumulated to commence work again. As the higher up the hill the tunnel was run the shorter it would be, they worked high to realize quicker, and frequently lost everything, never reaching the pay streak at all. As success depended on chance and not on skill, it is estimated that fully 75 per cent of these early ventures were failures. When the old channels become the subject of careful study the mistakes become fewer, the method as certain as others, and it has now become a very profitable branch of mining.

The amount of gravel in which the gold exists in drift-mining claims, is not less in extent than that which is worked by hydraulic mining, but the poor upper gravel cannot be extracted with a profit in drifting on account of its position under the volcanic rocks or poor gravel, and they must, therefore, be left and only the rich bed-rock section be worked. In many cases, these deposits are found in basins which are formed by the swelling of the bed-rock, so that for a considerable time there was a theory in vogue that the gold deposit was formed from lakes instead of rivers. The formation of these basins is owing to the fact that the ancient rivers differed in no respect from the modern ones. They were on a very much larger scale, however. They had the same bars, eddies, rapids and waterfalls, and the same peculiarities of the gold hiding itself away in corners and crevices. There were in these rivers, as in those of to-day, long barren stretches, and pockets or crevices which were of great richness. In the modern streams, such barren places are found from external indications without much difficulty, while in the ancient streams, covered with lavas, they must be sought for almost at haphazard. It often happens in these streams, as in the modern ones, that there was more than one channel—not unfrequently two and sometimes as many as three. They are not of necessity equally wide, but they must not be passed over if they are there, as the expense is nearly the same whether there are one, two or three. The problem of drift-mining is to find the "channels," to open them up with the least possible expenditure, and then to work them with the least possible cost. It is not always possible to find any surface indications of an old "channel." Some of the best mines worked at the present time, and nearly all those worked out and abandoned, were found by following the surface placers up to the line of the disappearance of the gravel and gold. At about this

point there is generally a "channel" opening, and here prospecting must be done. Sometimes a depression in the line or under edge of the country rock indicates an ancient "channel" and the probable presence of gold, but this cannot always be relied upon. Gravels, however, are not necessarily confined to a definite "channel," as in many cases the ancient streams, like the modern ones, overflowed their beds, carrying gravels and sands with them wherever they did overflow. Nearly all of these sands contain some gold.

Drift-mining has been brought prominently before the public by the débris legislation, because it was thought by some persons that it would solve that question, as it attacks the gold on the bed-rock, and less material therefore is washed, only the richest part of the claim being worked. The districts in California where this method is practicable may be said to comprise all the gold placer districts which have not been worked out. They are included within the counties from Mariposa on the south to Shasta and Siskiyou on the north. It is, however, in Nevada and Placer and Sierra counties that the most extensive claims are being worked at the present time. There are considerable areas in Plumas, Butte, El Dorado, Amidor, Calaveras, and Tuolumne counties which are being worked. As is well-known, the main axis of the Sierras, including the western slope of those mountains to a distance of from 10 to 40 miles from the summit, is granite. From the western edge of the granite, and overlying it, there is an immense body of metamorphic rocks. Of these rocks slate forms the largest part, limestone being the next. In a large area of the western part of Placer, Nevada, and El Dorado counties granite appears on the surface and is the ordinary country rock. The age of the slates and limestones, so far as can be determined, has been settled as Jurassic and Triassic. The quartz mines are contained for the most part in the granite and slate on the line of separation between the two formations. In some localities two distinct sets of ancient river channels have been found, one cutting across the other and so different in every essential characteristic that they were undoubtedly formed at very different periods.

The system is used on a large scale in Sierra County on the Blue Lead, an ancient river which is supposed to have its source in the high mountains of Plumas and Lassen counties. The channel has a width of 200 to 500 feet. Here the pay gold is quite coarse and is confined to a stratum from two to four feet from the bed rock. "The Blue Lead," as it is termed, has a grade on its

southerly course of from 50 to 175 feet to the mile. It was opened in many places as early as 1853, and has been continuously worked since that time. The returns from the early workings, comprising a distance of several miles upon the course of the channel, have been estimated from $200 to $300 per linear foot, as nearly as may be determined from the imperfect records of the early operations.

These gravels sometimes cover the whole surface of the country, without any apparent defined channel. There is also the greatest variation in the consistency of the volcanic rocks which cover them. Some of them are extremely hard, others thoroughly decomposed and easily separated. The channels are subject to a certain number of irregularities and disturbances and are sometimes even temporarily entirely cut off. These breaks are often called by the miners "lava flows," but as a general thing they are owing to the displacements of the bed-rock by the weight of the gravel above, or else they are disturbances caused by a movement of the pipe-clay. It is not an uncommon thing for the bed-rock also to swell, and in some instances it is extremely difficult to keep the tunnels open on account of it. Occasionally the bed-rock appears to rise and then to descend, and in many cases this has undoubtedly been induced by the additional pressure caused by the erosion of large bodies of the ground, leaving great spaces between the ends of the "lava flows," thus causing the bed-rock to bulge. When the bulge occurs in two places at some distance apart, it gives the appearance of a basin, and often when only two sides of it are found leads the inexperienced miner to suppose that his claim is worked out in that direction.

The gold in these deposits varies greatly in size. It occurs from fine float dust up to such nuggets as were found at Bald Mountain, which were from forty to sixty ounces in weight. Most of it, however, lies in a few feet of the gravel on the bed-rock, while the whole of the upper gravel is too poor to work. Some few of the present hydraulic mines were originally commenced as drift claims, when they sometimes yielded a larger profit than they now do as hydraulic claims. This kind of mining, which had almost fallen into disuse, was revived in 1872 and 1873, by the successful opening of the Bald Mountain claim of Forest City. At this place the North and Middle Yuba Rivers cut three distinct channels of the Pliocene Rivers at right angles, their course being nearly east and

west. The bars in these rivers had early attracted attention. Their richness was due to the erosion of the sand of these ancient channels. Of these channels the more easterly one has been covered in some places to as much as 1000 feet by volcanic lava and débris. The other channel, being on the border of the lava flow, has been very extensively hydraulicked. The centre of these channels is known as the Great Blue Lead. The course of the ancient river was nearly north and south and had a grade of from 70 to 100 feet to the mile. Its bed has an altitude of 4350 feet, being 1500 to 1600 feet higher than the beds of the North and Middle Yuba Rivers. It has been traced for 25 miles. This channel has been worked in a number of places. In some places, in order to work more advantageously, the different companies have connected their claims. The workings of the Alleghany and Forest City were so connected with a tunnel 6000 feet long. Between Rock Creek and City of Sixes there is a similar tunnel a mile long.

The skill required in this kind of mining is not so much in the method of doing the work as it is to be able to follow the ancient channels, which not only requires great ability in prospecting, but a very large amount of judgment and experience besides, for the claims rarely give any exterior evidence of their existence or any surface indications of their direction. They are almost invariably located on some more or less well-founded theory with regard to their direction.

The probable location of the channel having been determined by explorations, which have settled the fact that the claim contains pay gravel, a point is selected where a shaft is sunk to the bed-rock and drifts run in various directions from the bottom. The position of the channel having been determined in this way, a tunnel is run through the rim-rock so as to intersect the bottom of the channel in the shortest possible distance, in order to avoid a great length of tunnel, and when this has been done the mine is laid out with reference to its extent.

If what is supposed to be the entrance of a channel is found the tunnel is commenced some distance below the seam of "rim-gravel," as it is called, and run on light grade until it comes into the gravel or is supposed to be beyond the rim-rock, at which point a winze is sunk to the surface of the bed-rock in order to reach the gravel. This winze is usually at right angles to the direction of the channel and is inclined at a considerable angle.

The course, width, and grade of the channel are determined as near as can be with the least amount of work.

In order to determine the centre of the channel, the surface of the bed-rock is followed until it is found to rise and fall upon two opposite sides. It does not, however, of necessity follow that because two inclines in opposite directions have been formed that the end of the pay dirt has been reached, for it sometimes happens that the channel is divided or that there are elevations and depressions in it. An examination must be made to ascertain whether it is really the rim or only an accidental elevation or depression towards the sides of the channel. The main tunnel is carried up the grade of the ancient stream and gangways are run towards each bank. The gravel is taken out in cars and washed in sluices. The main tunnel is heavily timbered, so as to be always protected; but the side drifts are temporary and when the pay is removed are allowed to cave.

The depth of gravel that it has been found to pay to treat by this system is from three to five feet. The average will not be much over three feet. This includes three to six inches of the bed-rock, which is always picked down and washed with the gravel, as the lower part, including the bed-rock, is always the richest.

The following table gives the section of the ground on this channel between Bath and Forest Hill:*

Volcanic matter,	280 feet.
Quartz gravel,	12 "
Compact sand,	30 "
Sand and gravel, soft ground,	70 "
Pay gravel, upper lead,	8–10
Total,	400 feet.

The upper shale has been drifted up to a width of 400 feet. The channel has been several times lost but it has always been refound. At the Mayflower Mine, at a depth of about 200 feet below the hydraulic ground, a false bed-rock occurs, as it is called. It is compact, gritty material 140 feet in thickness, and is quite horizontal. Below it was found the lower lead of blue gravel, which

* Production of Gold and Silver in the United States, 1883, p. 719.

in the Paragon claim at Bath has been also reached. This is caused by the volcanic matter filling up an ancient stream. There occurred afterward a period of quiescence, and subsequently the waters flowed very nearly on the course of the former bed and over what is now known as the upper lead. This was succeeded by another volcanic flow, which effectually closed the ancient river, compelling its waters to cut out a new channel, which was the origin of the present fork of the American river.

The Forest Hill channel is an extremely interesting one, as the production of gold from it has been a million of dollars a mile in the aggregate. As a considerable quantity of ground had been exposed by denudation, the hydraulic process was adopted and successfully worked, but as the washing progressed into the hill, the superincumbent volcanic matter became thicker and tunnelling had to be resorted to.

The Hidden Treasure in Placer County is located on a channel running nearly north and south, its grade being to the south, about 70 feet to the mile. The tunnel, which is 3000 feet long, is run at this grade, and keeps 30 feet below the surface of the bed-rock in the channel. The Mountain Gate is located on the northern end of the same channel as the Hidden Treasure, and is only a few miles from it. The main tunnel is 6500 feet, and the channel above it has been worked out for that distance for a width of 200 to 250 feet. The channel has the same quality of gravel, the same grade, and is undoubtedly the same as the Hidden Treasure channel. 6500 feet in the channel is sharply cut off by lava, or cement, as it is called by the miners. An incline in this cement discovered another channel running northeast and southwest 80 feet lower than the original channel. It is about the same width as the other, but contains an entirely different kind of gravel, consisting of granite pebbles and boulders instead of quartz. The character of the gold is also different, being flake gold, nearly uniform, and of slightly finer quality. It contains a larger and richer body of gravel than the other channel, but it is worked at a good deal of disadvantage. It is generally considered that when two slopes of the rim in opposite directions have been found that the rim has been reached and the working is stopped in that direction. This is generally true, and is the rule always followed, except in the case of the accidents to the channel or bed-rock already referred to, when the channel has two or more "gutters." In such

a case the rim-rock must be followed up the incline until the "sand streak" or poor gravel coming down, gradually cuts out the pay gravel and the bed-rock is finally met. Generally, in such an exploitation, if there are several gutters, the inclined rock supposed to be the rim will turn down so as to give the indication that further exploration must be made.

A drift mine is always worked through a tunnel run into it from the hill side or from a ravine whenever practicable, so that its bottom will be either on or a little below the bed-rock with only just enough inclination to insure drainage. The location and construction of this tunnel is of the greatest importance. The success of the mine depends upon it. All the ground should have been previously prospected in order that this tunnel may be correctly run. Whenever it is impossible to reach the gravel by a tunnel, or where the latter would be very long or expensive, it is necessary to use vertical or inclined shafts. The first cost of reaching the gravel by a shaft is less than running a tunnel, but for taking out the gravel the tunnel is desirable, for in working by a shaft it would be necessary to raise all the gravel and mine water to the surface. Hoisting and pumping machinery would, therefore, be necessary, and would make an expensive plant. Practically it costs about as much to bring the gravel, in any mine extensively worked, from the point where it is mined, to the foot of the shaft, and load it into the cage or bucket, as to take it out in cars through a tunnel from 1500 to 3000 feet in length. A mine which is worked by a shaft must, therefore, have much richer gravel than if worked through a tunnel. Exactly how much richer depends upon how extensively the mine is being exploited and the cost of hoisting. Shafts, when used, are sunk to the bed-rock usually for exploring purposes, but are not generally used for exploitation. When water is plenty the hoisting is done by hurdy-gurdy wheels.

The location, elevation and course of the channel having been ascertained by shafts, a tunnel 7 x 9 feet is driven from the nearest practical point of the lower or down stream end of the ground. This tunnel must be securely and heavily timbered; after reaching the channel it is continued up stream, as nearly as possible in the centre of the channel, keeping either entirely in the bed-rock, entirely in the gravel or partly in bed-rock and partly in gravel. The gravel overhead is supported by timbering until the pay gravel for a con-

siderable area is removed. In order to prevent its crushing in the main tunnel the timbering is made very strong, and pillars are left in the ground 30 feet or more on either side of the main tunnel. When the limit of the claim has been reached these pillars are robbed. It will generally be necessary, in order to obtain sufficient dumping ground, to run an incline on the surface, from the mouth of the tunnel to the place where the dirt is treated. The inclination of this incline is usually 8 feet in 100. If the material used is to be stamped, it must deliver it into bins. If the dirt is soft it ends in a shute, which allows it to slide into the space where it is to be washed.

As for prospecting purposes tunnelling is quite expensive, where the top of the cement or gravel is not thought to exceed 150 feet a vertical prospect shaft is frequently sunk. Such a shaft can be made circular, and only large enough for one man to work at a time. It requires little or no timber, needs no hoisting machinery except a windlass, and costs, according to the hardness of the gravel, from $2.50 to $12 per foot. Drifts are run from the bottom of this shaft on the bed-rock, and the richness of the gravel ascertained. It is always advantageous to prospect by shaft because it is so much cheaper than tunnelling. It opens up much more ground with the same expenditure in very much less time, but is uncertain because the quantity of water which may come in may be so great as to make it beyound the control of the prospector.

It is not always practicable to open up a claim systematically. Sometimes the tunnel is not run low enough, and, instead of remaining in the bed-rock, comes out into the gravel. If in this case the bed-rock pitches off in the direction in which the work is being prosecuted, it may be necessary to run a new tunnel lower down. Whether necessary or not, will depend principally on the amount of water in the mine. If the tunnel has been run too low the gravel from the drifts will have to be dumped into a shute to be loaded into the cars below. If it is run too high an incline will have to be run to the bed rock and the gravel hoisted. When the expense of a regular tramway is not justified the ore is brought in large buckets, which are turned on their side and hoisted on two pieces of timber laid far enough apart to catch the sides of the bucket.

When the ground has been thoroughly prospected, and the

direction and width of the channel is known, the tunnel which is to serve the whole ground is run. The entrance, in order to secure, first, that the tunnel may be as short as possible; and second, that it may have the best facilities for washing, is generally commenced in a small ravine, which usually cuts into the mountain. Its direction should be such as to bring it in the bed-rock under the nearest point in the centre of the channel. Occasionally the conditions are such as will admit of its being run entirely in the gravel, but these are very exceptional. From this point the tunnel is run in the bed-rock on the line of the channel as the developments in the mine show what the course is to be. To keep the tunnel in the bed-rock its entrance must be much lower than the channel bed. What this depth must be depends upon the grade of the channel, its flow, the grade of the tunnel, and the length of the ground it is intended to work. All these, excepting the grade of the tunnel, are at the commencement of the work determined approximately only. It is better to have a tunnel much too low than a little too high, so a very liberal allowance is very generally made to cover possible errors of calculation from uncertain information. If the first tunnel is too high, it often necessitates running one or more tunnels lower down or working with interior shafts or winzes. The dimensions of the main tunnel, formerly adopted, are: height, 6½ feet; width, when not timbered, 5½ feet at the bottom, narrowing towards the top. The larger size of 7 x 9 feet is a better dimension. The posts are made from 10 to 20 inches in diameter, and for special purposes a diameter of 2 feet is not uncommon. Caps are generally 12 inches and upwards. The original method of making a nearly square tunnel has been abandoned in nearly all the large mines, and the system is now to make the main tunnel, for a single track, 7 feet on the bottom, 6½ to 7 feet high, and 3½ feet at the top, these measurements being in the clear. When double tracks are used the width is made 12 feet on the bottom. The object of placing the posts slanting is to prevent rapid crowding at the bottom in soft ground, which, with the posts set perpendicular, would cause very great delay and expense for repairs.

The tunnel is run into the mountain on a rising ground so as to secure drainage and make the transportation of the gravel easier. Grades varying from a quarter to half an inch in the rod are the lowest which are used. Those more usually employed are three

to four inches. In general, the lighter the grade consistent with proper drainage, the better. As the bottom of the channel, when reached, is never regular, and the grade of the tunnel must be, it will often cut into the bed-rock, which is no disadvantage when it contains gold, as it often does. Occasionally it will be in the gravel, but these irregularities are accidental and do not affect the general working. When the rock in the tunnel has a tendency to cave, to slide or to swell, it must be heavily timbered. If necessary, lagging is put on the top and on the sides. Timber which has been roughly squared with an axe is generally used. All that is to be used in the mine is generally cut, dressed, and delivered by contract at 8 to 12 cents for the single stick. Lagging costs usually from $20 to $40 per thousand. The wood used is generally the pine, spruce, fir and, cedar, which covers the ground of the claim, or grows near by. Usually enough can be obtained from the surface of the claim to supply all the wants of the mine. Men are employed by contract during the summer cutting timber and lagging.

The cost of running the main tunnel and sinking the shafts in the bed-rock depends entirely upon the character and hardness of the rock. In slate or other soft rock it will cost as low as $6 per foot, including the timbering and lagging. Harder rocks cost as much as $15 to $20. In blasting the harder varieties of rock, giant powder is used. Black powder is found most efficient in serpentines and similar rocks. The most economical way for the mine owner to run a tunnel, in fact, to do all the underground work, is by contract. When the main tunnel is run underneath the centre of the channel, a winze or an incline, the winze being preferable, is made through the bed-rock to the gravel. If it is not intended to continue the work any further, an incline is sometimes preferred, especially if the timbers and other material used in the mine are to be taken through it. They are always constructed in two compartments, one for the gravel and the other, containing the pipe, for the drainage and the ladder for the men. At the Bald Mountain extension mine in Forest City, the incline to reach the channel is 260 feet in length through lava, and makes a perpendicular rise of 60 feet. It is 50 feet above the main tunnel. This incline is, for a little more than half its length, a double track, and at the junction of the single and double tracks there is an automatic switch, which is set by the descending loaded cars. It

takes about thirty seconds to lower two loaded cars. A ¾ inch wire cable is generally used in hauling up five cars at one time. The empty ones are side-switched, and wait to be carried into the mine.

The drainage of the tunnel must be done by natural means if that is possible. Where there is a bed-rock tunnel below the workings, it is done through the lower tunnel. Usually there is a large amount of water in these channels. If the quantity to be handled is considerable, the water which collects in the mine-workings is conducted to a main sluice when the tunnel is in the gravel, or when the tunnel is in the bed-rock, to the several shafts, and, passing through them, runs either in a trough made under the tramway, or into a ditch at one side to a large reservoir tank at the entrance of the tunnel, in which it is stored to be used for washing the gravel. A pump of considerable capacity is almost invariably required in such mines when they are worked with vertical or inclined shafts. The flow of water usually increases as the mine is more completely opened, and is generally rather beyond, than within, the control of such pumping machinery as can usually be had. It sometimes happens that the tunnel running too high, will not permit of natural drainage, being from 10 to 20 feet higher than the bed-rock of the channel. In this case the running of a lower tunnel can be obviated by collecting the water in a sump close to the tunnel, and emptying it by means of a siphon. In some claims hurdy-gurdy wheels are used. The power developed usually ranges from 5 to 20 horse-power for each wheel. Sometimes small overshot wheels are used for pumping and for driving air-compressors and for motive power in the cement mills, but the wheels are usually of the hurdy-gurdy type. The same power is used for hoisting. At the Mabel Mine at N. Bloomfield the hoisting machinery of the dump-house is driven by a wheel 20 feet in diameter. The water strikes the wheel from a 2-inch nozzle under a pressure of 150 feet.

At the Mountain Gate mine, instead of allowing the waters to run into the lower tunnel, they are collected in a reservoir cut out of the bed-rock at the inner end of the old workings, 6500 feet from the outlet of the tunnel. From this tank there is a fall of 40 feet to the lower tunnel. An overshot wheel 30 feet in diameter is run from this tank, and furnishes power sufficient to pump all the water of the lower tunnel and raise the cars of gravel.

The method of extraction is not at all unsimilar to that which is employed in ordinary coal mining. When the pay gravel is reached it is cross cut from rim to rim, gangways are run at right angles, and the ground is stoped out in breasts. The main tunnel is always run ahead of the gangways. Pillars from 20 to 30 feet wide are left on each side to support it. It should follow as nearly as practicable the lowest point or gutter of the channel. The breasts are supported by temporary posts, or by piling up the large boulders and rejected material which have been found in the course of mining. As each breast is worked out the ground is abandoned and left to cave. The caving never takes place so suddenly as to endanger the lives of the men. Occasionally the swelling of the bed-rock below hastens the closing of the worked-out chambers.

Whenever the tunnel is run too low it is connected with the gravel by a slope, or when it is run too high the ground which can be worked with the first tunnel is used, and another tunnel must then be made below, for which reason they sometimes begin too low with the expectation of working up. The main gallery is generally 10 or 12 feet on the bottom, 8 or 9 feet high, and 3 or 4 feet wide on the top. The breasts are usually 3 to 5 feet in height. When the gravel must be carried to the surface by vertical or inclined shafts, the kind of motive power to be used depends on circumstances. If there is but little gravel, it may be raised by hand; if a large quantity, mule, horse or steam-power is used, or water-power, in the shape of a hurdy-gurdy-wheel, when water can be had. When there are no shafts or inclines, but little power is required, as the grade of the tunnel is usually sufficient to run out a train of two or three cars with one man at the brakes. When the quantity of gravel is very large, mine locomotives must be used. The cars with the timber and tools in them are returned by mules except when mine locomotives are used.

At the Mabel mine at N. Bloomfield the channel is not over 100 feet wide. The gangways are, consequently, very short. They are run from the main tunnel, 70 feet apart, alternating on opposite sides, so that the distance from the centre of the gangway is 35 feet. A pillar of 30 feet is left for safety on each side of this tunnel, and carefully preserved, as it constitutes the reserve of the mine, and when the deposit has been worked out is robbed. As soon as the

gangways have reached 30 feet from the main tunnel, breasts are started and all the ground that will pay is drifted out. Gangways parallel to the main tunnel are run outside of the breasts. The ground is broken, working forward from gangway to gangway, taking out all the ground that will pay, which sometimes is as much as 25 to 30 feet high. Sometimes the largest part of the gold is found within a foot of the bed-rock. In such a case, only just enough gravel is removed to enable the mines to work. This will make the workings from 3 feet to 3 feet 6 inches high. Generally from 4 to 6 feet is rich enough to pay. The cases where it will pay to take more than this are exceptional. At a comparatively small distance above, 20 to 25 feet, there may sometimes be another stratum of gravel that it will pay to drift. Three such pay streaks were discovered and worked in the Paragon claim at Bath, Placer County. The first was about 6 feet on the bed-rock, and some 10 or 15 feet higher a stratum of pay of about the same richness was found; then a third seam 150 feet above the bed-rock. This was worked through a separate tunnel. The roof is supported with ordinary posts and caps until the breast is worked out, when they are removed and the ground allowed to cave. The gravel is thrown by the drifters as near to the gangway as possible, when it is loaded into buckets or cars by the carmen, and pushed to the foot of the incline to be hoisted. When the distance to the foot of the incline is not great, the men can easily do this work. The men also run in the empty cars on their return. When the distance increases this work will be done by mules, or by a locomotive. The empty cars will be carried to the gangway, when they will be taken by the men as before. When the mine is in regular work after opening transportation by men is too expensive. It was found at the Bald Mountain mine that tramming by men cost 21 cents the load, by mules 9 cents, and by locomotive 4¾ cents per load. The rails used weigh 16 lbs. to the yard; they are the ordinary T rails. The gauge of the track is 18 inches. The cars are the ordinary box car, which holds ¾ of a ton of gravel, or platform cars made as low as possible, so that the men can easily roll large rocks on to them. Whatever rocks are taken from the mine are, as a rule, taken out entire. Occasionally one is found to be too large. It is then blasted by laying a piece of giant powder on top of it, covering it with sand, and then exploding it. This is, however, only done in the opening of the mine. As soon as the breasts are well

opened, and the bed-rock exposed and well cleaned, the rocks taken from the face are piled into the empty spaces and left there. The gravel of the Mabel mine is quite tight and requires blasting. The holes are made 20 inches deep, loaded according to the toughness of the gravel with from ½ to 2 sticks of giant powder. When it is necessary to enter the bed-rock, rock drills are used. The main tunnel is always run by gangs of picked men, who work the tunnel eight-hour shifts. It is kept as far ahead as it can be, and as near the centre of the channel as possible. The gangways running off to the rims show the deviation from the centre of the channel where there is any. About four car loads of gravel to a man is broken. This includes all the men at work in the mine. It varies somewhat with the amount of gangway work, the number of large rocks found in the gravel, and the amount of bed-rock to be cut up.

(To be continued.)

ON NEW FEATURES IN TELEDYNAMIC TRANSMITTERS.

BY PROFESSOR REULEAUX.*

(Continued from page 115.)

THE conception of a specific duty, which has proved so useful to us thus far, may also be brought to bear upon other types of power transmitters. So, to begin with, an examination of ordinary shafting in this light will certainly be interesting. If d = the diameter in mm. of a round shaft, and PR = the twisting moment, and $\mathfrak{S}$ = the torsional unit-stress exerted at the circumference, then $PR = \frac{\pi}{16}\mathfrak{S}d^3$.† Placing the lever-arm of the moment $R = \frac{1}{2}d$, P becomes the force in kgs. exerted at the circumference, for which we obtain $P = \mathfrak{S}\frac{\pi}{8}d^2$. Denoting the tangential velocity of the shaft in meters per second by v, and the horse-power transmitted by N,

* *Ueber Neuerungen in Ferntriebwerken*; an address delivered before the Railway Science Association in Berlin, Germany. Translated for the SCHOOL OF MINES QUARTERLY by Wheaton Kunhardt, E.M.

† See Theory of Strains, Stoney, edition 1873, p. 217.—TRANS.

we have $N = Pv \div 75 = \frac{1}{2}\mathfrak{S}\frac{\pi}{4}d^2v \div 75$. But $\frac{\pi}{4}d^2 = 100q$, when q denotes the shaft cross-section in square centimetres; hence, by reduction

$$N = \frac{2}{3}\mathfrak{S}qv,$$

from which we find, as before, for the specific duty of the shaft,

$$N_0 = \frac{N}{qv} = \frac{2}{3}\mathfrak{S}.$$

This expression for the specific duty is identical in form with the one deduced for wire rope transmission, but differs from it by being numerically smaller, since the unit-stress in the material, $\mathfrak{S}$, cannot be taken at as high a figure as in the first case, lest the twisting of the shaft should be too great. For shafts of medium weight (80–150 mm. diameter) $\mathfrak{S}$ is commonly 1.5—3 kg. per sq. mm.,* so that the specific duty for iron as well as steel driving shafts is reduced to $N_0 = 1$ to 2.†

To compute the area of cross-section q, the value of v must be introduced into the equation $N = N_0qv$. A velocity of 1 m. is al-

* If the actual distortion per meter shall not exceed ¼°, for a shaft whose length in meters is L between the points at which power is received and delivered, the maximum value of the torsional unit-stress at the circumference, $\mathfrak{S}$, may be found as follows (see the author's Konstrukteur, 4th edition, p. 39):

Let θ angle of distortion,

G = coefficient of torsional strength of the material = $\frac{2}{5}$ of the coefficient of elasticity = 8000, for both wrought iron and steel.

For θ we have in mm. of arc measurement, $\theta = \frac{\mathfrak{S}}{G} \cdot \frac{1000\ L}{\frac{1}{2}d}$; converting this into degrees by multiplying by $\frac{180}{\pi}$, and introducing for θ, G, and L their respective values ¼, 8000, and 1, we have $\frac{1}{4} = \frac{\mathfrak{S}}{8000} \cdot \frac{1000}{\frac{1}{2}d} \cdot \frac{180}{\pi}$ whence $\mathfrak{S} \leq \frac{d}{180}$. This develops the fact, incidentally, that the use of steel offers no advantage over iron for mill-shafting.

† Passing to English units as before, let P' = effective tan. force in pounds; $\mathfrak{S}'$ = torsional stress per sq. in. of the cross-section q'; d' = diam. in inches; v'' = velin feet per second; N'_0 = specific duty. Then $N = P'v'' \div 550 = \frac{1}{2}\mathfrak{S}'\frac{\pi}{4}d'^2v'' \div 550 = \frac{1}{2}\mathfrak{S}'q'v'' \div 550$, and $N'_0 = \frac{N}{q'v''} = \frac{\mathfrak{S}'}{1100}$. Assuming $\mathfrak{S}' = 2133$ to 4266 pounds per square inch (same as above), $N'_0 = 1.94$ to 3.88 = horse-power transmitted for each square inch of section and each foot of circumferential velocity per second.—TRANS.

ready rather high—at least, it is seldom approached and but rarely exceeded in our own practice, so that a very considerable quantity of material is required for each horse-power transmitted, a fact to which we shall have to refer later.

Another mode of dynamic transmission, whose importance has of late been gaining wider recognition, is that which utilizes hydrostatic pressures of 50 to 100, or 150 atmospheres, and even more. With the aid of accumulators, or pressure-storage apparatus,* this method is now used in driving a variety of machinery. After having been applied at first to cranes and riveters, and then to the Brand hydraulic rock drill and several other machines, always with most satisfactory results, it has of late been introduced at several places in England for purposes of general power distribution from a central station through an extended network of conduits.† Keeping to the customary appellations of belt transmission, and rope transmission, we may with the same convenience speak of water transmission—or here, particularly, of high-pressure water transmission.‡

In determining its specific duty, importance attaches not so much to a consideration of the liquid power conveyer as to the metallic conduit, since the latter covers the principal item of expense. If d denotes the diameter of the conduit pipe, and p the pressure and v the velocity of the fluid, all in metric units, then the horse-power transmitted will be $N = \frac{\pi}{4} d^2 pv \div 75$. To find the thickness of the pipe, θ (in mm.), assuming a unit-stress $\mathfrak{S}$ in the material, we have, with sufficient accuracy for our purpose, $dp = 20\mathfrak{S}$, whence $\theta = \frac{1}{2} dp \div \mathfrak{S}$. But the cross-sectional area of the wall of the pipe, expressed as before in sq. cm., is $q = \pi d\theta \div 100$, or substituting here the value of θ,

$$q = \frac{\pi d}{100} \cdot \frac{d}{2} \cdot \frac{p}{\mathfrak{S}} = \frac{\pi}{4} d^2 \cdot \frac{2}{100} \cdot \frac{p}{\mathfrak{S}}.$$

Deducing from this the value of $\frac{\pi}{4} d^2$, and introducing it into the expression for the horse-power N, we obtain

---

* *Spannwerke*: see author's Konstrukteur, 4th edition, p. 260.

† See, for example, Glaser's Annalen, 1883, vol. xiii., p. 180; and Zeitschr. des Ver. Deutsch. Ingenieure, 1884, p. 776.

‡ *Riementrieb, Seiltrieb, Hochdruckwassertrieb.*

$$N = \frac{100}{75} \cdot \frac{q}{2} \cdot \frac{\mathfrak{S}}{p} pv = \frac{2}{3} \mathfrak{S} qv;$$

and hence, for the specific duty of water transmission, or, in general, of any fluid transmission,

$$N_0 = \frac{N}{qv} = \frac{2}{3} \mathfrak{S} *.$$

Both of these expressions are particularly noteworthy, from the fact of their demonstrating that *the specific duty of water transmission is independent of the water pressure.* In other words, whether the water be used under high or low pressure, with the same velocity of flow the same horse-power will be transmitted for each square centimeter of wall cross-section in the pipe, provided that in proportioning the thickness of the pipe the same unit-stress $\mathfrak{S}$ is assumed in each case.

This unit-stress in the material of pipe conduits is, however, variously regarded by engineers. The use of a high safety factor is generally deemed necessary in order to meet all kinds of empiric requirements, such as cheap transportation without breakage, deterioration from rusting, influences of temperature, etc. Accordingly for large low-pressure conduits none but very moderate unit-stresses can be introduced into the above formula, whereas for the newer high-pressure pipe, serving under 50, 100, 130, and 150 atmospheres of pressure, the case is more favorable. Pipes both of wrought iron and steel, riveted as well as drawn and welded, are employed in such service with unit-stresses which are

* In English units let d' = diam. and θ' = thickness of pipe in inches; q' = cross-sectional area of the wall of the pipe in square inches, and $\mathfrak{S}'$ = unit tensile stress; p' = pounds pressure per square inch, and v'' = velocity of water flow in feet per second; N'_0 = specific duty. For the horse-power transmitted, we have $N = \frac{\pi}{4} d'^2 p' v'' \div 550$; the thickness of the pipe is practically proportional to the diameter and pressure, or $d'p' = \theta' \mathfrak{S}'$, whence $\theta' = \frac{1}{2} d'p' \div \mathfrak{S}'$. But $q' = \pi d' \theta'$; and hence $= 2 \frac{\pi}{4} d'^2 \cdot \frac{p'}{\mathfrak{S}'}$. Solving this with respect to $\frac{\pi}{4} d'^2$, we have $\frac{\pi}{4} d'^2 = \frac{1}{2} q' \frac{\mathfrak{S}'}{p'}$; introducing this into the expression for N, we find $N = \frac{1}{2} q' \frac{\mathfrak{S}'}{p'} p' v'' \div 550 = \frac{1}{1100} \mathfrak{S}' q' v''$ from which $N'_0 = \frac{1}{1100} \mathfrak{S}'$ = the horse-power transmitted for each square inch of cross-section in the wall of the pipe and each foot of current velocity per second.—TRANS.

far from insignificant. For wrought iron we may safely place $\mathfrak{S}$ at 2 to 3 kg. per sq. mm., and for steel possibly as high as 4 to 6 kg., which would make the specific duty of water transmission

$$N_0 = 1\tfrac{1}{3} \text{ to } 2 \text{ for wrought-iron pipe,}$$
$$N_0 = 2\tfrac{2}{3} \text{ to } 4 \text{ for steel pipe.*}$$

As the water pressure p does not enter into the expression for N_0, very high pressures will prove advantageous by economizing in the size of the conduit pipe. Nor need such increase of pressure be limited through fears of great frictional resistance, for with all but excessive velocities of flow, and with due avoidance of eddies, friction is independent of it.

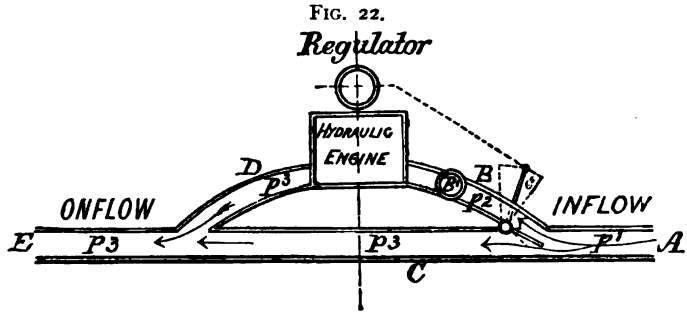
From the foregoing it must, therefore, be apparent that water is excellently adapted for teledynamic transmission, promising results in this field which may possibly bear favorable comparison with those of wire rope. To examine this question by the test of figures will be a matter for later consideration. First, however, I would remark that water can also be used in circuit transmission, and in this respect, therefore, ranks by the side of wire rope. Heretofore, it is true, no mention has ever been made of using water in this way, but the principle was equally novel for wire rope, and its application to water is clearly indicated by analogy when one recognizes that in both cases a body advancing under internal strain yields up at each point of power delivery a portion of the effort it conveys, and then, less strained than before, but otherwise unchanged, continues its course and is subject to further and repeated reductions of strain, until finally the surplus energy, or excess of strain, imparted to it at the motor station is completely exhausted. If a current of water be thus conducted through a line of pipe which returns into itself—that is, through a pipe circuit—the water will be capable of yielding up power at every delivery station in its course without parting with any of its body.

The diagram (Fig. 22) shows the general arrangement of a water-pressure engine, or point of power delivery, designed to secure this end. The inflow pipe A divides at the delivery station into two branches, B and C; the first, or inlet, branch leads to the

* In English units with the same values as above, viz., $\mathfrak{S}' = 2844$ to 4266 pounds per square inch for wrought iron and 5688 to 8532 pounds for steel, we find $N'_0 = 2.6$ to 3.9 for wrought iron, and $N'_0 = 5.2$ to 7.75 for steel.—TRANS.

engine which abstracts from the water a certain portion—$\frac{1}{10}$, $\frac{1}{9}$, $\frac{1}{3}$, or any other fraction of its potential energy. At the fork of the pipe a fly-valve C' is introduced, controlled by a tachometric governor, which is actuated by the engine itself, and must be of ample power.* The outlet D from the engine rejoins the branch C, forming with it the onflow of the conduit E. Let us assume a pressure (molecular strain) p_1 in the water current of the inflow-pipe and suppose the engine at rest, the stop-valve B' having been shut by hand, while the fly-valve C', which previous to the stoppage had been automatically controlled by the regulator, has now

FIG. 22.



closed the inlet branch B completely. The water then flows under the initial pressure p_1 into the section C, and thence further into E, maintaining a constant pressure. If under these conditions the

* Suitable governors would be those of Ganz, in Ofen, Hungary, and of Luede, in Berlin, both depending on the principle of a set escapement (*Stellhemmung*, author's Konstrukteur, 4th edition, p. 259). Various types of water-pressure engines, and chamber-wheel engines like that of Behrens' (author's Ther. Kinematics, sec. 100), may serve for taking up the power. With a view to automatic regulation, hydraulic crank-gear engines have lately been designed with a crank of self-adjusting length. Such is Hastie's engine in England (Engineer, August, 1878, and April, 1880), which, however, is open to the objection that the governor is dynamometric, and therefore only acts correctly for variations of resistance, while for variations of motive pressure it cannot possibly work right. A happier, and eminently successful, result has been obtained by Helfenberger, in Rorsbach, Switzerland (Imperial Ger. Patent 12018), whose engines under most carefully conducted tests and greatest variations of pressure show an efficiency of 90 per cent. and even more—the head of water being 360 m., and the power developed 20 to 40 horse-power—demonstrating beyond question the high economic value of water-pressure engines fitted with crank gear. With the engine placed in a dynamic circuit, as above detailed, there is no need for refined governors, as the simple pressure regulator adjusts the stress on either side of the piston, and loss of power is not to be apprehended, since the current carries away for further utilization all the energy which is not used.

engine is to be started, the valves B' and C' must be opened to permit a flow through the inlet branch B. Presently the engine begins to move; the regulator is then connected with the fly-valve C', whose position it immediately adjusts in accordance with the normal engine speed. If much power be used it sets the valve so that p_2 at the engine becomes a large fraction, or, if little, a small fraction, of p_1; p_3 is then the residual strain, and as this operates as back pressure against the engine, the effective effort of the latter is reduced to p_2-p_3, a quantity which is constantly brought up to the required measure by the regulator.

Obviously the details of this station engine have to be specially developed. The water which flows away from the first delivery station under a pressure, or internal strain, p_3, may be utilized at further points of the circuit in similar engines, and so on around to the motor station. If on arriving there the water should, as a rule, have reached its lowest pressure, it may be discharged into a basin, from which the motor pump will again raise it; but if its pressure is not, as a general thing, completely exhausted, the last out-flow pipe might connect directly with the suction pipe of the motor pump, so that the latter could restore to the current its initial energy, and drive it once more into the circuit.

Circuit water transmission should be particularly well adapted where the delivery, or working points, are spread over a wide field, but yet admit of being connected throughout by a simple conduit. It presents an obvious advantage over the older system of separate discharge at each station engine, when a non-freezing mixture of water and glycerine is to be used in the pipe.*

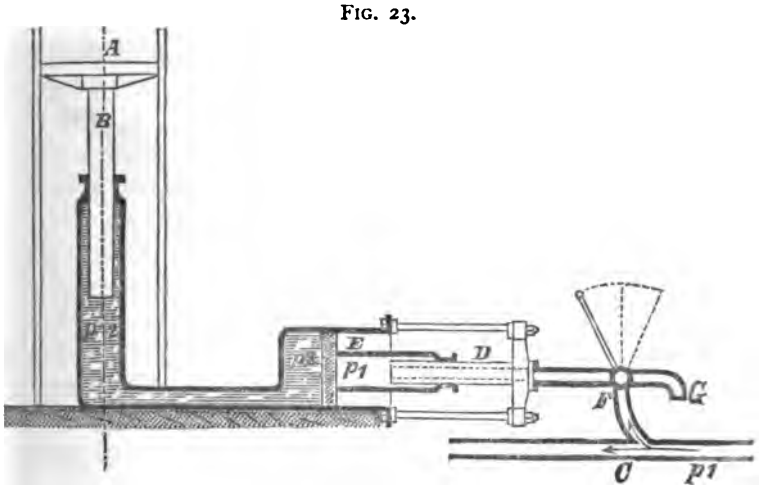
Among the places to which this new system would be well suited we should count the great union dépôts, whose erection at important railroad junctions has, as already observed, become more and more of a necessity. Then there are the many work-shops, and dynamos, and other machines which require the delivery of power at isolated points; and in the enumeration we should not omit the power lifts, which, with constantly increasing traffic, are daily coming into greater demand at large railway stations. In each case it may be a question which of the two

* Incidentally it may be remarked that within limited areas, controlled by a central management, the effectiveness of a few gas jets in warming the pipe sufficiently to keep plain water from freezing, has been abundantly shown in the use of the Armstrong hydraulic cranes.

hydraulic systems—that of circuit transmission, or the older one of separate water discharge—should be preferred.

In order to express by a convenient name this last, or older system, and at the same time have a designation which may apply equally well to the corresponding methods of wire rope, and other dynamic transmissions, I would suggest the term *linear transmission* for any system in which the transmitting agent does not pass through all the points of power delivery and return upon itself to form a closed circuit. Accordingly the older method of using wire rope is linear rope transmission, as distinguished from the circuit rope transmission which I have described; and our hydraulic

FIG. 23.



system is linear water transmission when the spent water is discharged at each engine, and circuit water transmission when the engine returns the water to the service pipe.

For the railway dépôts, where we have proposed to use water in the distribution of power, I am inclined to believe that no single, one-sided system would answer as well as a mixed system embodying both linear and circuit transmission. Such a combination may not only be favored by local conditions, but may also prove most suitable where there is an intention of using hydraulic lifts, as these can be more readily adapted to a linear than to a circuit system. An apparent difficulty in diverting a linear train from an otherwise closed circuit, lies in the tremendous pressures, ranging from 750 to 2250 pounds per square inch, which prove so efficient

for circuit transmission, but which would, in the case of a lift, reduce the diameter of the ram to such extremely small proportions, that its crushing resistance would not suffice to carry the loaded platform. This is easily overcome, however, by the introduction of a hydraulic—or, more correctly, a hydrostatic—quick motion gear, or water lever, as the contrivance might be called. Its principal features are outlined in diagram (Fig. 23). A is a platform of the usual kind supported upon a ram B, which is worked by low-water pressure (300 to 375 pounds per square inch). This pressure is obtained from that in the high-pressure service-pipe C by the interposition of a three-way cock F (or any valve of like action), two plungers D and E whose cross-sections are respectively proportional to p_1 and p_2, and an outlet G for the spent high-pressure water. No difficulty would be encountered in designing such a lever, so that its further detailed treatment need not detain us here.

* * * * *

Before proceeding, however, I may be permitted to introduce a few observations regarding the wide survey which we may obtain through our conceptions of circuit and linear power transmission. The old mode of driving water-wheels and turbines by the side of a natural waterfall with an open mill-race is "water transmission"—a very low pressure transmission, it is true, for the ordinary wheel, though sometimes a fairly high one for the turbine when pipe takes the place of the open flume. Both are examples of a linear dynamic train. If one should wish to push the idea further, meteorologically or cosmographically, and consider the evaporation of the water from the sea and its reconveyance to the mountain heights as the last step in a dynamic circuit, such an extension to cosmic processes would certainly prove invaluable in framing any broad general conception, but it would be departing from an engineering view of the subject. For it is new water, falling water in general, and not the identical same that has but just passed through the wheel, which now hurries toward it, borne down from the mountains by the mighty forces of nature. And when this water is spent it runs downward still, to broader currents which flow in lower levels, and reaches at last the lowest one of all, the broad plane of the sea. Into this general descent of the water, or rather into a single course, or "line," of it, our mechanical linear transmitter is introduced. The windmill

similarly depends on a linear dynamic train, for it is impelled by a current of air falling from high altitudes to which it has been raised by the earth's warm zones. The steam-engine is likewise actuated by energy linearly transmitted, since its prime mover is the thermo-static head produced by a boiler fire; it is driven by steam falling from the thermal level of the boiler to that of the exhaust, or, lower still, to the level of the condenser. The experiment of operating the steam-engine in a dynamic circuit has been repeatedly tried (by Siemens and others), but never with lasting success, though a sort of circuit system is applied wherever the exhaust steam of powerful high-pressure engines is used for driving those of inferior capacity.

In Lehman's hot-air engine there is a true dynamic circuit, though only for one piston, while Ericson's caloric engine and all of its successors furnish illustrations of a linear dynamic train. A linear train, too, is that applied in Paris for driving engines by the vacuum system, to which we have already alluded; a pump at the central, or motor, station of the plant exhausts the air from an extended network of pipe, while the engines, variously distributed in the dynamic field, are actuated by atmospheric pressure and discharge spent air into the pipe. Our ordinary electro-magnetic telegraph also illustrates linear transmission of energy, though at first sight it may seem more like circuit transmission. The galvanic battery takes electricity from the earth, and raising it to a certain potential—*i. e.*, imparting to it a certain tension—sends it forth to the working point, where it drops again to the earth's potential level. But true dynamic circuits, it should be said, are not at all impossible in the department of electro-mechanics.

While artificial electric cataracts, chemically or mechanically produced, are being used on every hand, the natural fall of the earth's current is allowed to remain unutilized—not but that some attempts are being made, however, to intercalate a linear train in its course, for the current, though extremely weak, is immensely broad, and should therefore be capable of furnishing power. In a thunderstorm nature produces tremendous electric cataracts, which, at the moment of discharge, precipitate themselves upon the earth like floods from the mountains, devastating and destroying like these, unless specially provided channels, the lightning-rods, conduct the current safely to the lower plane. An immense quantity of mechanical work thus passes unutilized into the earth, just

as in former times all the work of water's natural circuit was "wasted." And the parallelism naturally suggests the query: will a second Franklin ever succeed in so dominating the electrical storm-floods as to render them not merely harmless to man but useful to him as well?

* * * * *

Returning after this brief digression to our consideration of the agents employed in engineering practice for teledynamic transmission, we had found that in sundry aspects their relative values could be illumined by taking account of their specific duties; but no complete comparison of the different transmitting methods, at least so far as a disregard of constructive details would permit, had as yet been possible. For this purpose one element was still wanting, namely, a determination of the quantity of material in the transmitting body. An investigation of this question appears quite practicable, and may possibly establish general points of reference, even though no decisive judgment could be reached without a special knowledge, or, to put it quite practically, without an estimate of cost for each individual case.

In any system of transmission the quantity of material required for the principal power-conveyer can be expressed by the horse-power which one kilogram of the material transmits for a given distance between the power and working points. This may be called the *specific teledynamic value** of the system, for if it is large the method of transmission is advantageous, while if small the method will prove less favorable wherever distance plays much of a rôle.

For the specific duty of ordinary shafting—or, to repeat our former definition—for the horse-power transmitted per square centimeter of shaft cross-section, and per meter of circumferential velocity, we had found

$$N_0 = \frac{N}{qv} = \frac{2}{3}\mathfrak{S},$$

and for the horse-power which the shaft is capable of transmitting,

$$N = N_0 qv.$$

Now let G denote the weight of the shaft for a given length in meters, A_0, between the power and the working points, and de-

* *Specifischer Ferntriebwerth.*

note its specific gravity. For the weight we find, after expressing the volume of the shaft in cubic decimeters,

$$(3) \qquad G = 10 A_0 \frac{q}{100} \sigma.$$

Dividing the expression for N by this last one, we arrive at our desired result. We have only to assume a fixed and absolutely conventional value for A_0, which we will take at *10 meters*, and then, denoting the quotient $N \div G$ by N_x*, we obtain for the specific teledynamic value of the shaft

$$(4) \qquad N_x = N_0 \frac{v}{\sigma} = \frac{2}{3} \frac{\mathfrak{S} v}{\sigma}.\dagger$$

But this value $N_0 v \div \sigma$ applies to all the cases we have considered, with only this reservation, that for linear transmission with belting and rope, where the flexible transmitter has both a driving and a slack side, the one advancing and the other returning, the formula becomes

$$(5) \qquad N_x = \frac{N_0}{2} \frac{v}{\sigma}.$$

In circuit rope transmission, on the other hand, formula (4) holds good, since there only a single rope passes over the course. The numerical values derived from these formulæ are particularly noteworthy, as they reveal unexpected differences in the various systems of transmission. Where high velocity is coupled with great unit-stress in the power conveyer, a very high specific teledynamic value is obtained, but where both of these quantities are small, their occurrence in the formula as factors, one multiplied by the other, reduces the teledynamic value very considerably. The following table (p. 232) exhibits the relations deduced for a limited number of transmitting agents.

---

* The index x suggests the distance 10 (meters). With different units of measure other distances can be assumed for A_0.

† In English units let A'_0 = length of shaft in feet; q' = its cross-section in square inches; v'' = tan. vel. in feet; N'_0 = specific duty, σ = specific gravity; and G' = weight of shaft in pounds. Then $G' = A'_0 \frac{q'}{144} \sigma\ 62.4 = \frac{1.3}{3} A'_0 q' \sigma$. We also have as before, $N = N'_0 q' v''$. Assume $A'_0 = 30$ feet, and introduce this into the expression for G'. Then dividing, as above, and denoting the quotient $N \div G'$ by N'_{30}, we obtain $N'_{30} = N'_0 \frac{v''}{13\sigma} = \frac{\mathfrak{S}'}{14300} \frac{v''}{\sigma}$ = the specific teledynamic value, *i. e.*, the horse-power which each pound of the shaft, moving with a tangential velocity v'', transmits for a distance of 30 feet.—TRANS.

Power Transmitter.	Metric Units.*				Proportions.	%
	v	$\mathfrak{S}$	N_0	$N_{\mathfrak{S}}$		
Steel Rope, Circuit Transmission.....	30	15	10	38.46		100
Steel Rope, Linear Transmission.....	30	15	10	19.23		50
Iron Rope, Circuit Transmission.....	30	7.5	5	19.23		50
Iron Rope, Linear Transmission.....	30	7.5	5	9.61		25
Leather Belt, Linear Transmission.....	30	0.38	$\frac{1}{5}$	6.00		15.6
Hemp Rope, Linear Transmission.....	30	0.17	$\frac{1}{12}$	2.50		6.5
High-pressure Water, Steel Pipe.....	4	6	4	2.05		5.3
High-pressure Water, Iron Pipe.....	4	3	2	1.03		2.7
Steam, Steel Pipe.....	4	3	2	1.03		2.7
Steam, Cast-iron Pipe..... ...	4	1	$\frac{2}{3}$	0.34		0.9
Shafting, Iron or Steel.....	1	3	2	0.26		0.7

* In English units v' = hundreds of feet per minute, and v'' = feet per second. The rates of speed are in nearly, though not quite, the same ratio as in the metric table, giving rise to slight differences in the column of percentage relations. The unit stress $\mathfrak{S}'$, is practically the same as above.—Trans.

Power Transmitter.	English Units.					Power Transmitter.	English Units.				
	v'	$\mathfrak{S}'$	N_0'	$N_{\mathfrak{S}}'$	%		v''	$\mathfrak{S}'$	N_0'	$N_{\mathfrak{S}}'$	%
Steel Rope, Circuit Transmission...	60	21,330	32	18.93	100	High-pressure Water, Steel Pipe....	15	8530	7.75	1.14	6
Steel Rope, Linear Transmission...	60	21,330	32	9.46	50	High-pressure Water, Iron Pipe....	15	4260	3.88	0.57	3
Iron Rope, Circuit Transmission...	60	10,660	16	9.46	50	Steam, Steel Pipe.....	15	4260	3.88	0.57	3
Iron Rope, Linear Transmission...	60	10,660	16	4.73	25	Steam, Cast-iron Pipe.....	15	1420	1.30	0.19	1
Leather Belt, Linear Transmission..	60	540	0.64	2.95	15.6	Shafting, Iron or Steel.....	3	4260	3.88	0.12	0.63
Hemp Rope, Linear Transmission..	60	240	0.28	1.22	6.5						

The unit-stress in the transmitter and the velocity of the latter are given in each case with what may be regarded as practical, experimentally determined, maximum values. The preponderance of rope transmission, especially with steel wire, is very noticeable, and yet the conditions here assumed for wire rope do not even set it on its best footing—not at least for powerful plants, as in these the employment of a counter pulley, or idler, at the motor station, both in the circuit and linear methods of transmission, would reduce the modulus of tension τ to $\frac{2}{3}$ of its normal value, and raise the specific duty to $1\frac{1}{2}$ times the original amount, *i. e.*, make $N_0 = \mathfrak{S}$*. The corresponding value of N_x has purposely been omitted, because the use of the idler will hardly be common practice.

Fully as marked by contrast as the immense preponderance of wire rope is the exceeding smallness of the specific teledynamic, or transmitting, value of shafting. Its position at the very foot of the list certainly furnishes food for reflection in considering power transmission in extensive mills and machine shops,† and points to the decided advantages, under certain circumstances, of the circuit rope system. High-pressure water transmission with steel pipe has a teledynamic value of 2.05, which is fully eight times as much as that of shafting, though amounting to only 2.7 per cent. of the transmitting value of steel-wire rope. But no direct comparison between steel rope and water should be based on this percentage, as a wire rope plant may be altogether impracticable where water transmission would answer well, and *vice versa*. Besides it is to be remembered that bearings, standards, conduits, branch pipe, etc., require special estimates in every case, and under many conditions exercise a strong influence on the relative values.

Steam transmission, even with steel pipe, is shown to have a far lower teledynamic value than water transmission—lower, indeed, than one would have expected. This may have its influence in future in determining the style of underground pumping and hoisting engines, more especially as water transmission admits of exceedingly high pressures, and hence very small pipe, whereas steam

* See author's Konstrukteur, 4th edition, p. 836 *et seq.*

† In some large yarn mills the total length of shafting amounts to more than 1000 m.; an American mill, in regard to which data are at hand, is furnished with 2455 hangers; assuming an average distance between these of only $2\frac{1}{2}$ m., the aggregate length of shafting must exceed 8 km.

absolutely demands the use of large pipe, which can only be protected with great difficulty from losses of heat. With water at 3000 pounds pressure as against steam with at most 75 pounds, one could use for the former a service pipe of less than one-sixth the diameter required for the latter. Here, again, a mixed system of circuit and linear transmission would appear to offer the most advantages.

But a word more, and that upon the hurtful resistances, or losses of useful work, which occur in the different teledynamic systems. These losses, occasioned by friction, stiffness of cordage, resistance in the agent, eddies, radiation, etc., cannot be put into such simple expressions as those which we found above. The differences in the power conveyers will always make it necessary to treat each method of transmission in this respect by itself. Nevertheless a general review of the relations may be obtained, as we shall presently see, which will furnish some sort of common connection.

The greater the horse-power which one kilogram of the power-conveyer can transfer over a certain distance, the smaller, for any such conveyer of given capacity, will be the load which has to be supported by bearings or the like, and the less, therefore, by reason of the smaller masses involved, are the losses, *cæteris paribus*, from friction, and shock, and eddies, and radiation. In other words, and generally, at least, *the proportion of the hurtful resistance diminishes, as the specific teledynamic value of the transmitter increases.* The table of teledynamic values presents in a measure, therefore, a view of the relative losses of useful work; for the values of N_x are, if not exactly in inverse, yet in opposite, proportion to the corresponding losses from hurtful resistance, so that the net, or effective, values of N_x are more favorable than the above computed and tabulated gross values—more favorable in the sense that the higher values of N_x lose far less than the lower ones in substracting the losses of work.

This could hardly be more clearly shown than by comparing wire rope and shaft transmission. For example: In the iron wire rope plant at Oberursel, to which we have once before referred, the loss of work at present amounts to 14 per cent. of the 104 horse-power which are furnished by the turbine and transmitted over 966 meters, the distance between the power and working stations.* For shafting the loss of work due to journal friction,

* No consideration is here taken of the possibility of reducing this loss to only 4 per cent. by carrying out the plans of improvement which I have suggested.

computed with a coefficient of friction 0.08, and a length of line A, is equal to $A \div 950$ for each square centimeter of shaft cross-section and each meter of circumferential velocity. This *specific loss of work* in our particular case amounts to $966 \div 950 = 1.02$. But when $v = 1$ and $\mathfrak{S} = 3$, the total work imparted to each square centimeter of shaft cross-section is $N_0 = 2$, so that the loss from friction may be figured in round numbers at 50 per cent. The effective element, therefore, in the specific teledynamic value of linear iron rope transmission, instead of being 25, as in the table, is at very worst not less than $25(1 - 0.14) = 21.5$; whereas for shafting, with a tabulated transmitting value of 0.7, the effective value would only amount to $0.7(1 - 0.50) = 0.35$. In the place of a relation of 25 : 0.7 without the subtraction, we find for the useful or "effective" teledynamic values a ratio of 21.5 : 0.35, or, in percentages, 35 to 0.5. No less than 52 horse-power would be absorbed in journal friction of the shafting, and since at low water the turbine only gives 40.3 horse-power, it could not in such seasons rotate the shaft in its bearings. That such and similar results must necessarily be obtained, is readily appreciated when we consider that wire rope is run at a high speed and with high unit-stress, and is supported on anti-friction rollers, which revolve at a very low velocity (about $\frac{1}{80} v$); while on-the other hand the shaft is subjected to but very moderate stress, and can only be run at a low velocity, at the full rate of which, however, it has to overcome the friction of its bearings.

Such reviews reveal very clearly the usefulness of our conceptions of a specific duty and a specific teledynamic value, and hence, perhaps, both may be deemed suitable for more general acceptation in engineering theorems.

THE DURANT-EMMA CASE.

BY WILLARD PARKER BUTLER.

OF THE NEW YORK BAR.

ON December 23d last, the jury in the United States Circuit Court for the District of Colorado rendered a verdict for the plaintiffs, in the ejectment suit of Hymen and others against

Wheeler and others, and thereby decided in favor of the apex location as against the side-line location.

This verdict has made great stir in the mining world, and has given rise to much comment in the daily press throughout the entire West, as well as in the leading professional journals. As far as the daily press is concerned, the importance of this case has undoubtedly been overestimated, for, under the law of Colorado, in a suit of this character the defeated party is entitled to two new trials, as a matter of right; and, in addition to that, in the present case an appeal would undoubtedly lie to the Supreme Court of the United States. Thus it will be seen that the judgment entered upon the verdict in this case is far from being final, even if the verdict had been rendered in strict accordance with the facts; and that, unless some compromise is effected, the question involved is not likely to be settled until after some years of wearisome litigation.

The excitement caused by this case, unimportant as it is, suggests in a striking manner the imperfections of the existing mining law, and, if the case shall serve to direct the attention of the public to the practical difficulties and objections to the enforcement of that law, it will have indeed done good service.

Here was a case where both parties were insisting upon a diametrically opposite state of facts, but where they otherwise started out upon what was, to all intents and purposes, an equal footing. The case came up for trial before one of our most experienced Federal judges; the number of expert witnesses, upon each side, was limited to an equal number; both sides had the benefit of equally able counsel, and equally experienced experts; the jury was about equally divided between the mining and agricultural counties of the State; the judge interpreted the law, in his charge, with proper fairness, and appears to have made but one error in admitting evidence, which he subsequently corrected, as far as was in his power, by telling the jury not to consider the same; but, nevertheless, what is said by some to be, a mere paper-enterprise, is to prevail against a legitimate mining industry. No hints have been made that the jury had been "fixed," as far as I can gather, but yet, in a case of the direst uncertainty of facts, the apex has been victorious as against the side line; and, unless the defendants are victorious hereafter, or the law be modified or abolished, prop-

erty in a side-line location will no longer be a desirable thing to hold or to develop.

I have not read the testimony in this case, or anything further than the judge's charge; but that is of little consequence, for the question which should be asked by every one who hears of the verdict, is not "Is the verdict in this particular case warranted by the evidence?" but, "Ought not a law which can give rise to such conditions of uncertainty, and to controversies of the character of the present one, to be abolished in the interest of the commerce and development of the country?" And it is in this particular respect that the case offers a most instructive lesson.

Some months ago, the Supreme Court of the United States defined what was a proper charge, in cases involving the law of the apex; and went out of its way to compliment Judge Hallett upon his success in defining the law, in the case of the Iron Silver Mining Company *v.* Cheeseman. In a short article in the *Quarterly* for July, 1886, I made some comments upon that case. I was apparently wrong at that time in supposing that juries would be likely to find "no continuity" in doubtful or divided cases, and that the effect of that case would be practically to abrogate the existing law; for, in the present case, in which the experts were equally divided as to the character of the deposit, the jury was willing and ready to find upon the evidence, a vein within the meaning of the statute. The fact that there exists a possibility that such cases can be decided in favor of the apex theory, affords an urgent reason why the existing law should be changed.

In the Durant-Emma case, the Court seemed to be of the opinion that there was an apex in the Durant location, for Judge Hallett says in his charge: "Upon the testimony of the defendant's witnesses alone, there is scarcely any reason for doubt as to the presence of an outcrop or apex in the mouth of the Durant incline." There was also no doubt but what the plaintiff was the legal owner of the Durant claim. With these assumptions, the case is precisely similar to the Iron-Smuggler case, referred to above as the case of the Iron Silver Mining Company *v.* Cheeseman, and the question was simply; Was, or was not, the vein worked in the Emma a continuation of that whose apex was possessed by the plaintiff? It is upon this particular point that the law now seems to fail. It seems to be comparatively easy, in view of the definitions heretofore given in the various courts, to deter-

mine whether an apex is found or not, or, at least, that point has not been so often in controversy, but the question of continuity seems to be much more uncertain, and at the moment much more uncertain than it was when Iron Silver Mining Company *v.* Cheeseman was last decided, when it looked as if juries would practically be unwilling to find the existence of veins within the meaning of the statute, except in notoriously clear cases.

The Denver *Daily News*, of December 24, 1886, contained an editorial from which I quote the following statement of the views taken by the two parties. "The plaintiff showed that the Durant incline had been run on a continuous body of ore, which lay between blue and brown limestone; that it had every feature of a true fissure or contact vein; and that the outcrop of said vein was within the limits of the Durant claim. The defendants showed that no outcrop existed within the Durant side lines; that the Durant incline was run on barren ground; that it disclosed no semblance of any kind of a vein; that it had been driven on a closely welded contact of blue and brown lime; that the ore in the Emma, Aspen, and adjoining workings, existed both in blue and brown lime, without any defined boundaries; that the only way to determine the difference between pay-ore and country-rock was by assay; and that the deposits were merely ore-zones or impregnations."

All that the jury had to decide then, was, whether there was a vein extending upward from the Emma ground into the Durant and outcropping there within its side lines.

The fact that the plaintiff claimed that this was a fissure vein caused Judge Hallett to slightly modify his charge, from that of the Iron Silver *v.* Cheeseman case, in defining a vein. "The character," he said, "of a vein or lode, and the country adjoining it, can be better and more satisfactorily shown through extensive works than in a small area. What weight shall be given to the fact of the persistence of the ore throughout these claims, is to be determined by the jury. Without something in the plaintiff's claim to show a crevice or a continuous ore or mineralized rock, it would be of little value. In connection with evidence showing, or tending to show, a crevice or a continuous ore or mineralized rock, it would be of little value. In connection with evidence showing, or tending to show some such fact, it may be of considerable value. If you find from the evidence that the ore in

the several works is in the form of a brecciated vein, in a fissure between walls, the extension and continuance of such fissure throughout the territory mentioned by the witnesses may be more readily predicted than the same fact as to the ore or mineralized rock only. Upon that point a part of the charge, in the case before mentioned, is fully applicable in this case."

He thereupon gave, word for word, that portion of his charge in the case of the Iron Silver Mining Company *v.* Cheeseman that had been approved of by the Supreme Court, so far as it related to the determination whether a lode or vein existed or not. This portion of the charge in that case has been so much commented on that it may well be quoted in this connection in full:

"To determine whether a lode or vein exists, it is necessary to define those terms; and, as to that, it is enough to say that a lode or vein is a body of mineral, or mineral-bearing rock, within defined boundaries, within the general mass of the mountain. In this definition the elements are, the body of mineral or mineral-bearing rock, and the boundaries; with either of these things well established, very slight evidence may suffice as to the existence of the other. A body of mineral, or mineral-bearing rock, in the general mass of the mountain, so far as it may continue unbroken and without interruption, may be regarded as a lode, whatever the boundaries may be. In the existence of such body, and to the extent of it, boundaries are implied. On the other hand, with well-defined boundaries very slight evidence of ore within such boundaries will prove the existence of a lode. Such boundaries constitute a fissure, and if, in such fissure, ore is found, although in considerable intervals and in small quantities, it is called a lode or vein." Hymen *v.* Wheeler, 29 Fed. Rep., 347.

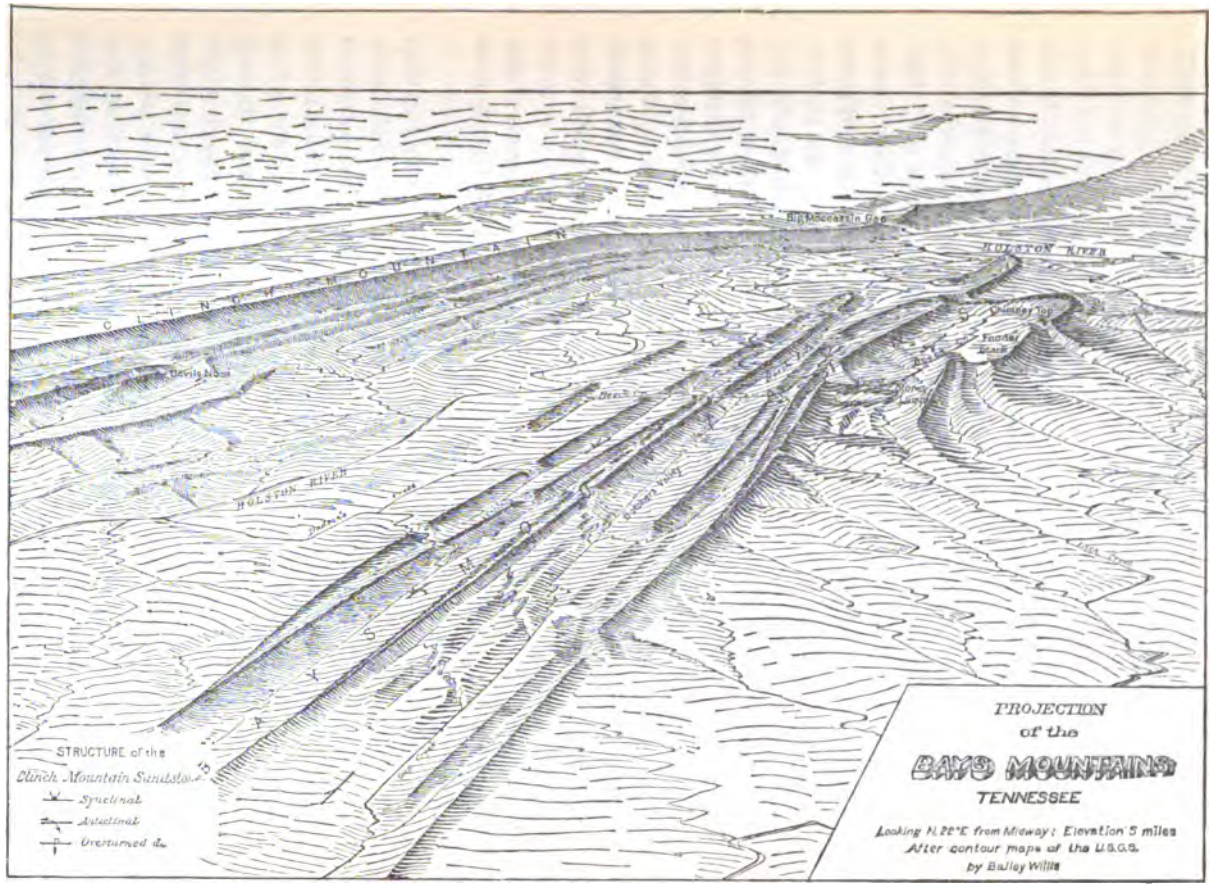
These words appear as long ago as June, 1882, in the first Iron Smuggler case, and are found in Dr. Raymond's "Law of the Apex," at page 410, of vol. xii., of the *Transactions* of the American Institute of Mining Engineers.

The jury concluded that the evidence proved the existence of a lode within the meaning of the above definition, and that it extended from the Durant downward into the Emma, notwithstanding the testimony of the defendant's experts showed that the Durant incline had been run on barren ground, that it disclosed no semblance of a vein, and that it had been driven upon a closely welded contact of blue and brown lime.

Here the resemblance to the Iron-Smuggler case ceases. In that case, upon a similar state of facts, except, however, the existence of the alleged fissure-vein, the jury found, on the first trial, for the defendant, *i.e.*, against the apex; on the second trial they disagreed; and, on the third trial, the verdict was again for the defendant. In neither the first nor the third case was the jury willing to find that continuity which is necessary to prove the existence of the vein. When this charge was announced to be correct, I had supposed in view of the outcome of the previous trials, that as far as doubtful cases are concerned, the statute would practically be unenforceable. This view has turned out to be erroneous. In the present case the jury has been willing to find a vein; apparently, for the reason that the plaintiffs claimed that such vein as they had, was a fissure-vein.

Such a state of uncertainty is deplorable, and must become intolerable. Who can afford to develop a mining location when a reckless outsider is at liberty to follow a visionary vein down into it, and claim the cream of it, provided that he can find a jury sufficiently bold to help him? And this appears to be quite possible. As one of the Denver newspapers said, "a man might just as well lay claim to the sea because he has a brook running through his land which enters into it." It is the duty of every one interested in the mineral resources of this country, and their development, to do all in his power to secure the modification or abolishment of our most unique and unreasonable mining law.

FIG. 1.


HOLSTON RIVER
HOLSTON RIVER
STRUCTURE of the
Clinch Mountain Sandstone
Synclinal
Anticlinal
Overturned do.
PROJECTION
of the
BAYS MOUNTAINS
TENNESSEE
Looking N.28°E. from Midway: Elevation 5 miles
After contour maps of the U.S.G.S.
by Bailey Willis

TOPOGRAPHY AND STRUCTURE IN THE BAYS MOUNTAINS, TENNESSEE.

BY BAILEY WILLIS.

In the valley of East Tennessee, midway between the North Carolina ranges and the long crest of Clinch Mountain, a short distance south of the Virginia line, a group of parallel ridges stands out in sharp relief from the surrounding knobby country. Daniel Boone is said to have given them their name of "Bays Mountains" through association with a bay horse. Their elevation is 500 to 1800 feet above that of Lick Creek on the southeast, and of the Holston River on the north and northwest, the highest point being Chimney Top, 3075 feet. Their general trend is N. 50° E. from their rise from the Nolachucky River to their failure, where the Holston flows around their northeastern end, a distance of 41 miles. Across their mid-section their width is about 6 miles, but toward either end the outer ridges fall away, leaving but a single low representative to reach the Nolachucky, while two, extending with prominence almost to the Holston, unite in a gentle curve.

Within the elliptical area thus defined, sharp sandstone crests and wooded slopes divide narrow valleys, now cultivated, now abandoned to dense laurel thickets.

The southwestern half is drained toward the south by Gap Creek and lesser tributaries of Lick Creek, and toward the west by Dodson's Creek. Beech Creek collects most of the waters of the northeastern area. The latter stream rises near the eastern edge of the group, flows southwest parallel to the ridges to a point opposite the greatest width of the mountain belt, and turning sharply northwest, cuts its way in narrow gorges through eight ridges of hard sandstone. This course is the more remarkable because the upper valley is eroded from soft calcareous shales, which continue on their strike in the southwesterly direction, that the stream abandons, and which would seem to have offered a surface of least resistance, upon which it must have carved its channel.

Professor James M. Safford refers in his Geology of Tennessee to the Bays Mountains in connection with the physical geography

of the State (p. 43), and in his account of the Clinch Mountain sandstone, and describes their geologic structure on page 298. Although the general facts have thus been stated with that accuracy which renders Professor Safford's work a source of surprise to those who have followed him with the advantage of good maps and facilities for special surveys, I have nevertheless deemed it worth while to contribute some of the results of such later work, and to suggest the problems presented by the surface geology.

Their isolated position as a group, attracts attention in a region where long continuous ridges are the rule. Like Clinch Mountain, they owe their existence as elevations to the core of hard sandstone contained in each ridge, but unlike that extended divide, they terminate very abruptly after a short course in the direction of their strike.

Their intersection by the Holston and Nolachucky has been determined by causes as yet imperfectly known, and is paralleled by many other cross-cuts, such as that of Beech Creek.

It is rather their failure to continue beyond these rivers in either direction, that is peculiar, and is explained by relations of geologic structure to surface slope.

If we ascend the end of any one ridge, we shall find that the capping sandstone lies horizontally, or with but slight dip, in the direction of the mountain trend upon the soft shales that make up the mass; following along the height, it divides into two, frequently of equal elevation, in each of which the sandstone is highly inclined toward its twin outcrop. That is, each ridge is a monoclinal, and dies out when it merges into its counterpart at their common synclinal axis. Two adjacent pairs are in some instances united at the axis of the intervening anticlinal, in other cases the sandstone is entirely eroded, and a comparatively broad valley is cut from the gray shales beneath.

The synclinal structure of these component pairs is a characteristic of the group as a whole; it is surrounded by older rocks, dipping in its vicinity toward it.

This elliptical mountain area is, therefore, at the horizon of these sandstones, the base of a trough, the minor flutings of which appear in the alternating folds of the group.

In the process of degradation the high relief of this region is determined by the occurrence of the sandstones, but the tendency of this rock to maintain a ridge is limited by the law governing

stream profiles. Accepting for the moment the factors that enter into that law, as given us, and considering the profiles they determine as elements of a surface rising from a base level at the Holston and Nolachucky rivers towards the Bays Mountains, the intersection of that surface with the sandstone platter of the group defines their area. This intersection is a closed circuit, and the group is, therefore, limited in all directions.

Were the great synclinal, which is the locus of the mountain area, a simple basin, the ridges might be replaced by a single broad topped elevation, bounded by a sandstone escarpment; but the minor flutings are sufficiently bold to raise sandstone arches above the limit of surface elevation, and the erosion of these elevated crowns has exposed softer strata, isolated special areas of sandstone, and subdivided the relief into many ridges.

If we cross the group from south to north, we pass the Stony Lump synclinal, the upper Beech Creek anticlinal, the synclinal of the several central ridges, the Butchers Valley anticlinal, the monoclinal heights that rim the valleys of the deepest trough, the valley of the northern anticlinal, and the synclinal outliers along the northern edge of the group. It is apparent that synclinal corresponds with mountain, anticlinal with valley, except on the line of the deepest lying synclinal axis; and the exceptions do not contradict the general law, that the arch becomes a hollow, the basin a ridge, where erosion penetrates the hard sandstone stratum.

It is to be noted, too, that structure determines the degree, as well as the locus, of topographical relief; the greater number of ridges lie south of the central axis of the basin, and their height increases with the rising surface of the sandstone to its maximum along the southern rim.

The Bays Mountains are then the product of structure, rock resistance, and position of base level; the two first are given, the last is constantly sinking in relation to the adjacent mountains. For the rate of corrasion by the swift currents of the Holston and Nolachucky is more rapid than that of their branches, and progresses still faster than the degradation of the sandstone crests.

Given the same material to work upon, the rivers have the advantage over their tributaries in volume, greater amount and character of abrading material carried, and the more frequent occurrence of floods during three-fourths of the year. Their fall is sufficient to sweep their rock beds clean, and direct evidence of

their greater cutting power is afforded by the cascades, by which their tributaries join them. It has been often remarked that the gorges by which the rivers traverse the Great Smoky range are in fact cañons; but it is less generally recognized that this is true also of their courses in the Valley, at least as far down as Knoxville. Of the many streams emptying into the Holston, the Nolachucky, the Clinch and Powell's river above Knoxville, I know of but one, Lick Creek, which has been able to reduce its valley to the stage of deposition. As far up as Laurel Gap it is a sluggish creek, with cut banks of gray mud, the residue of the calcareous shales from which the entire valley is excavated. The softness and solubility of this material enable the creek to keep pace in erosion with the river. Corrasion of the river beds being most rapid, it follows that the mountains are growing relatively higher; the relief of the surface is increasing.

The general elevation of the Bays Mountains referred to a constant sea level, is slowly lessening; referred to surrounding valleys it is less slowly increasing; the heights of individual members of the group are changing in their relations to each other less slowly still, for they offer an unequal resistance to the process of degradation.

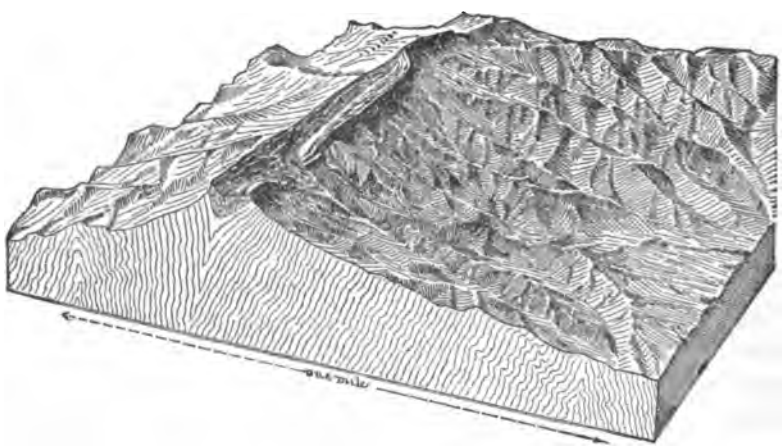
In the central ridges of the group, where the sandstone dips at a high angle into the mass of the ridge, and is covered by vegetation, erosion is almost nil. Where, on the contrary, the sandstone forms a nearly horizontal cap, the shales spread under its pressure, the rigid covering separates into polygonal blocks, bounded by vertical cleavages, and the summit is rapidly narrowed by lateral loss. This process is beautifully illustrated in Chimney Top, where the chasms between sandstone prisms are five to ten feet wide, and the remnant of the cap is rarely a hundred feet across, with a thickness of seventy-five feet. The slopes below its precipitous escarpment range from 20 to 35 degrees; their steepness is determined by the slight resistance offered by the soft shales, sustained by the protecting cover, at a height far above that at which they could maintain themselves against existing erosive agencies. It follows that with the destruction of its sandstone summit, a period of relatively very rapid degradation will begin.

The Fodder Stack and Stony Lump are structurally closely related to Chimney Top; each is developed from a distinct synclinal wrinkle at the base of a common trough. In Chimney Top

the horizontally bedded sandstones represent only the lowest part of its minor fold; in the Fodder Stack the axis and southern side remain, and in Stony Lump the basin is visible as a depression in the summit of the mountain, elevated 1300 feet above the adjacent valley. Thus, of these three, the first is the most, the last the least advanced toward the stage of degradation to the general level of Lick Creek Valley, which is, geologically speaking, near, and will antedate the disappearance of the monoclinal ridges of the centre of the group.

When these prominent outliers shall have been degraded, the tributaries, received by Lick Creek from their lessened slopes, may not improbably cut back the divide, till upper Beech Creek

FIG. 2.



Model of Stony Lump.

is tapped by some one of them. The diverted waters will reduce their valley to the level of that of Lick Creek, the gorge by which Beech Creek now passes through Stone Mountain just below Van Hill, will become an air gap, and a rivulet will feebly continue to cut the channel descending westward.

It would not be difficult to trace out further possibilities of this process of differential and retrogressive erosion, but it is more to the purpose to trace the development of the present topography by these or other methods from its past phases.

It is a fact, emphasized by various writers, that drainage systems originate when land surfaces emerge from the ocean, and tend to perpetuate the relations of valleys and divides till the topography is reduced to a base level.

What then was the character of the river system, which developed on the emergent surface, over the locus of the Bays Mountains group?

If general uplift antedated flexure, wandering streams subject only to accidents of slope and inequalities of the ground, first resulted; if subsequent folding upraised arches less rapidly than such antecedent streams corraded and without such sinking of troughs, as to change the general slope, the valleys were maintained in spite of structure. This is the simplest hypothesis by which to explain the intersection of mountains by rivers, but it fails when conformity of topography and structure is the rule, unconformity the exception.

If, on the other hand, flexure was contemporaneous with uplift, the Bays Mountain area became a trough, either through the simultaneous formation of its entire anticlinal rim, or through the successive elevation of one crown adjacent to another. The sections show the result to have been a long flat basin traversed longitudinally by subordinate arches.

In course of uplift the anticlinal rim being most prominent emerged first and formed a divide, discharging waters on its inner slope into the basin. Erosion began with the first appearance of land, and for a time the height of the divide was the excess of elevation over the work of degradation. But when the entire rim was above the sea, the water surface within the basin became the base level for drainage flowing into it; the lowest point of the rim became the outlet for this nascent lake, and the relief of the long peninsulas and islands, formed by subordinate arches, equalled the excess of cutting over surface erosion.

The deepest trough of the basin was the last to be drained, and it received the streams flowing from the minor synclinal lakes or valleys on either side; for each of the latter discharged over the lowest point in its adjacent arches, and this was somewhere on the inner margin.

When the principal outlet was cut low enough to completely drain the basin, there resulted a central longitudinal stream, fed by many parallel currents through cross-cut valleys. Each of

these long-valley streams was made up in turn by small branches, flowing from the anticlinal divides.

The two hypotheses suggested: that of antecedent drainage lines maintained in spite of flexure, and that of emergence of the flexed surface fully developed, are the extremes. Between them fancy may run free with their combinations, tending now to the purely accidental on the one hand, now to the alternative of coincidence of synclinal and valley on the other. But under no assumption can the primary drainage system have presented the anomaly of streams flowing parallel to each other along structural elevations. Since the excavation of valley from anticlinal, and the elevation of synclinal to mountain top is the rule of the present relief, it follows that some process has modified the law of conservatism of drainage, and has transferred an equally systematic topography laterally, through the space between synclinal and anticlinal axes.

Before it was thus shifted the topography of the Bays Mountains trough must then have presented a number of parallel synclinal valleys.

In the process of degradation of the intervening anticlinal divides long outcrops of hard rock occurred upturned with softer strata. By differential erosion such harder rocks formed ridges, or lines of knobs, whose trend was in the direction of the strike. When such a stratum as the gray shales under the Clinch Mountain sandstone was exposed, the ridges or knobs became prominent along either side of the axis, and a chain of minor valleys resulted along the divide, drained by cross-cut channels across the sandstone. Topography of this character is of common occurrence in the valley, and the sketch (Fig. 3) differs from observed facts only in the positions of its structural axes.

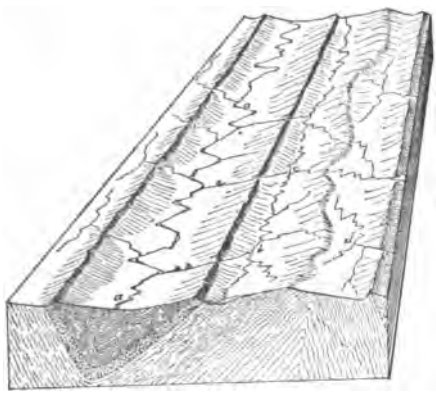
If under these conditions any tributary (*b*) had a slightly larger watershed than (*c*) and (*e*), it, by virtue of its greater volume, sunk its channel more rapidly than they, and widened its area of supply at their expense. The advantage once gained, however slight, was increased until (*b*) had cut its lines in the softer rocks to a slope, controlled by the lowering of its mouth. The divide between (*b*) on the one side, and (*c*) and (*e*) on the other, was cut back by (*b*) until it joined the slopes drained by (*c*), which descended toward (*b*).

The stream (*b*) was then lengthened at a jump to the head of

(*c*), and the latter was soon reduced to that portion of its channel, between (*a*) and the line of harder outcrops.

Thus increased in volume, (*b*) must have deepened its channel, and, consequently, extended its watershed, and by repetitions of this process, inevitable if it be once begun, (*b*) must have continued to grow at the expense of tributaries of (*a*), until its headwaters met with some stream doing equal retrogressive work. It at the same time widened its valley to the outcrops of hard rock on either side of the axis. The characteristics of (*b*) were then: an anticlinal valley eroded from soft rocks, bounded by monoclinal ridges of harder strata, and a sharp turn and short course at right

FIG. 3.



Sketch of Consequent Drainage.

angles to the strike. These are the features which mark upper Beech Creek, the north fork of Beech Creek, and a part of Dobson's Creek.

The existence of a synclinal implies two adjacent arches; two parallel anticlinal divides, and hence two possible anticlinal valleys. If the stratigraphic conditions necessary occurred on one side of the synclinal, they were in all probability equally marked on the other side, and the development of one anticlinal valley was likely to be accompanied by that of its counterpart beyond the trough. The discharge of both was directly or indirectly toward the central axis of the basin. The intermediate stream, robbed of its supply from both sides, corraded less than its lower course, undiminished below the mouths of the retrogressive watersheds. The latter soon sank through the hard stratum of the trough into the

softer shales, and cutting with increased rapidity, isolated its upper valley on a mountain top. The characteristics of a ridge thus determined would be a cap of hard rock, traversed lengthwise by a synclinal axis, and by a stream discharging at one end. (Lookout Mountain.) It is possible that at some stage of this process a tributary of the stream (*b*) (Fig. 3) should have tapped the stream (*a*) by cutting back the divide of hard rock; the resulting synclinal ridge would then be capped as before, but its drainage would discharge laterally. (Stony Lump.)

It is thus apparent that differential and retrogressive erosion are adequate to explain some of the relations of topography to structure in the Bays Mountains, and the tendency of the discussion is to establish the relation of antecedent and consequent between a drainage system that originated probably at the close of the Carboniferous and one existing now, but the connection may easily be sketched too closely.

Palæozoic time is long past; if degradation has gone on continuously Appalachian topography should bear the marks of great age, elevations should be low and relatively as well as absolutely declining; the region should have advanced far towards a base level. This is not so; heights are considerable and are relatively increasing, profiles are bold and rivers fall rapidly to the estuaries of a submerged coast. The relief is young and contradicts the age of the land surface.

We arrive at a similar result if we compare the amount of degradation suffered with that determined elsewhere. The thickness of strata removed from above the Bays Mountain area is 5000 feet, including the Mountain limestone above and the Clinch Mountain sandstone below; that removed from above the adjacent anticlinal near Rogersville is 13,000 feet, from the Knox sandstone below to and including the Mountain limestone above. To these should be added perhaps 1000 feet or more of Subcarboniferous sandstone.

And this is the work of both Mesozoic and Cenozoic time. Post-eocene degradation of the Alps varies from 4000 to 8000 feet (A. Heim, *Mechanismus der Gebirgsbildung*, vol. ii., p. 97). Post-cretaceous denudation of portions of the Great Basin has reached 30,000 feet (Uinta Mountains, J. W. Powell, and Fortieth Parallel Survey, Clarence King). 3500 feet of Cretaceous strata have been taken from above the Henry Mountains, and to this may perhaps be added something of the Tertiary (G. K. Gilbert). Arches of

Laramie coal measures of Washington Territory have been cut down until sections measuring 8000 to 13,500 feet are now exposed.

Making all allowances for inaccuracy in these figures, they justify the statement that the work performed by erosion over the Bays Mountain area since Palæozoic time does not exceed that accomplished elsewhere since the early Tertiary, that is, in one-fourth the period.

Rate of degradation of a general land surface is determined by two conditions, water supply and fall. If there be no rain, nothing is carried off; and drainage ceases to transport when its current fails.

The Appalachian region was a peninsula between two broad water surfaces from its uplift until late Tertiary time. Arid conditions are therefore out of the question, and, indeed, we rather have ground to believe that for a long time, abundant moisture so stimulated vegetation as to arrest widespread erosion. Such is the present condition on the western slope of the Cascades; but we can there see that corrasion is none the less active because general degradation has ceased. Streams are deeply countersunk and the progress of the surface toward a base level is but temporarily retarded by a sharper division of the process into two stages, those of cañon incision and subsequent lateral expansion. Thus we are led to the alternative hypothesis, that for a prolonged period rivers had not sufficient fall to transport sediment. That is to say, the area was reduced to a base level.

Triassic sandstones deposited in estuaries along the Atlantic indicate that the shore line lay outside the present coast; flexure had not ceased, since the deposits were made in deepening synclinals, but denudation had begun, else there had been no sandstones. There is no evidence of submergence until the middle of the Cretaceous; that which then began lasted, interruptedly, perhaps, until the Pliocene.

The existence of a constant relation between sea and land during a prolonged period is a condition favorable to the production of a very low surface relief; slow submergence of the coast line of such a land surface must have hastened the development of a base level plain.

Upon such a plain vertical corrasion was insignificant; horizontal corrasion became important. By ever-widening sweeps to right or left river courses approached or separated from each other, and the direct channels determined by structural causes

were exchanged for indirect and tortuous routes to outlets, perhaps, often far removed from the original mouths.

Upon the elevation of such a plain rivers meandering through its alluvial and residual deposits would sink with accelerated currents; their waters would perpetuate their major sweeps and cut their channels indifferently across or along the edges of the upturned strata.

With time details would be modified by differential and retrogressive erosion, but the great systems of a drainage, thus superimposed, would remain characterized by irregularity and at strange variance with structural facts. Such are the features of southern Appalachian drainage, more strikingly apparent by a glance at a map than through any extended description. And thus the drainage systems themselves lend evidence of their derivation from rivers of a base level plain.

With a desire to know more about this vanished level, beneath which the present mountain ranges were but buried possibilities, we may question its extent and relations to the ocean. Its culmination could not have been below the highest summits of the Black Mountains of North Carolina, yet it could have been but slightly elevated above the level of the Cretaceous and Tertiary shore line. Hence it follows that the present crest of the Appalachians was nearly at sea level in post-cretaceous time, and that the subsequent movement was a differential uplift, unaccompanied by flexure, very slight on the coast and in the Mississippi basin, but which reached nearly 7000 feet in western North Carolina.

This difference seems at first sight great, but it is almost a vanishing quantity compared with the span of the arch. If the latter but extended across North Carolina and Tennessee its chord was 850 miles, and the ratio of height of arch to half its chord was as 1 : 300. This is equivalent to a rise of 17.6 feet per mile or a slope of 12 minutes.

The lines of discussion followed in this paper spring mainly from facts of the surface geology. It is some years since the importance of the relations of drainage to structure has been appreciated by geologists, as by Powell, Gilbert, and Dutton, who have studied such problems as a continuation of the history, which stratigraphic geology drops with the last retreat of the ocean. But the text-books do not yet give the clews to the genesis and development of river systems, and the subject presents the fascination of a little-explored territory, rich in possibilities.

ON THE ACTION OF SULPHUROUS ANHYDRIDE ON BENZENE.

BY CHARLES E. COLBY AND C. S. McLOUGHLIN.

WHEN benzene is treated with sulphuric anhydride the elements of water are eliminated, and a compound is formed containing the group SO_2 attached to two phenyl radicles. This body, first prepared by Mitscherlich,* was called by him sulpho-benzid; more recent investigators have given it the name of diphenyl-sulphone. It occurred to the authors that an analogous reaction might be possible between benzene and sulphurous anhydride, thus giving rise to a body containing the group SO combined with two phenyl radicles.

Benzene dissolves sulphurous anhydride in large quantity, but no reaction takes place between them unless condensing agents are present. Friedel and Crafts† found that a mixture of benzene and aluminium chloride absorbs sulphurous anhydride with great energy forming benzene-sulphinic acid. They explain the reaction thus:

$$C_6H_6 + Al_2Cl_6 = C_6H_5Al_2Cl_5 + HCl.$$
$$C_6H_5Al_2Cl_5 + SO_2 = C_6H_5SO_2Al_2Cl_5.$$

They then add water, and thus obtain benzol-sulphinic acid.

$$C_6H_5SO_2Al_2Cl_5 + H_2O = C_6H_5SO.OH + Al_2Cl_5OH.$$

We repeated these experiments, and, after several trials, proceeded in the following manner:

One hundred grams of benzene and 35 grams of aluminium chloride were placed in a flask fitted with a return condenser. The flask was heated on a water-bath, and a stream of sulphurous anhydride was passed through it by means of a tube dipping below the surface of the benzene. The sulphurous anhydride was rapidly absorbed, the aluminium chloride gradually dissolved, and hydro-

* E. Mitscherlich, Liebig's Annalen der Chemie, 12, 208.

† Friedel and Crafts, Jahresbericht über die Fortschritte der Chemie, Giessen, 1878, 739.

chloric acid gas escaped. The operation was continued as long as the sulphurous anhydride appeared to be absorbed. The current of the anhydride was then stopped, but the flask was heated till no more hydrochloric acid gas was evolved. The contents of the flask were allowed to cool and then poured into cold water. The precipitated aluminium hydrate was then dissolved and washed away by means of caustic soda. There remained a light yellow oil, which was separated from the aqueous liquid, dried with calcium chloride, and then allowed to evaporate at a gentle heat. The excess of benzene being thus removed, there was left a dirty yellow crystalline substance. This, when dissolved in xylol, and left to itself, deposited small transparent isolated crystals, apparently belonging to the triclinic system. They were of a yellowish waxy color, but on recrystallization from petroleum ether they became perfectly white. Their melting-point lies between 70° and 71°; they are easily soluble in alcohol, ether, glacial acetic acid, and benzene; difficultly soluble in cold petroleum ether, more readily in hot.

An ultimate analysis furnished the following results:

I. 0.2039 grm. substance gave 0.5318 grm. CO_2, and 0.0957 grm. H_2O.

II. 0.2502 grm. substance gave 0.6540 grm. CO_2, and 0.1164 grm. H_2O.

III. 0.1689 grm. substance gave 0.1907 grm. $BaSO_4$.

Collecting these figures—

	I.	II.	III.	Theory for $(C_6H_5)_2SO_2$.
C, ...	71.13	71.28	.....	71.286
H, ...	5.21	5.16	.....	4.950
S, ...	.....	.....	15.51	15.843
O, ...	.....	.....	.....	7.921
				100.000

A portion of the substance was dissolved in ten times its weight of glacial acetic acid, and oxidized by adding the calculated quantity of potassium permanganate. After diluting with water, and crystallizing the resulting precipitate from alcohol, there were obtained white crystalline plates of diphenyl-sulphone, melting at 128°. The yield was almost theoretical.

Another portion of the substance, on treatment with two molecules of metallic sodium, furnished diphenyl sulphide, boiling at 272°.

These results lead us to the conclusion that the body produced by the action of sulphurous anhydride on benzene in presence of aluminium chloride is diphenyl sulphoxyde, $C_6H_5.SO.C_6H_5$.

We have also tried the action of thionyl chloride ($SOCl_2$) on benzene in presence of aluminium chloride. The reaction is:

$$2C_6H_6 + SOCl_2 = (C_6H_5)_2SO + 2HCl,$$

and is analogous to that of oxychloride of carbon (phosgene) on benzene in presence of aluminium chloride.

In preparing diphenyl sulphoxyde by means of thionyl chloride we proceeded as follows:

Fifty grams of benzene and 16 grams of thionyl chloride were placed in a flask fitted with a return condenser, the flask being immersed in cold water. Aluminium chloride was then added, in small portions, to the mixture in the flask. The aluminium chloride was rapidly dissolved, and hydrochloric acid gas escaped. The addition of $AlCl_3$ was continued at intervals as long as HCl gas was given off. Altogether 30 grams of $AlCl_3$ were used. Toward the end of the operation 20 grams more of benzene were added to make the mixture more fluid. When fresh addition of $AlCl_3$ produced no further evolution of HCl gas, the flask with its return condenser still attached, was heated on a water-bath for half an hour, then allowed to cool, and the contents poured into cold water. A thick yellow oil resulted, which floated. This oil was washed with water, and then gently warmed in a dish to remove surplus benzene. On cooling, there resulted a yellowish waxy mass, which, when crystallized from petroleum ether, furnished white crystals of the same form as those described above, and possessing the same properties. Their melting-point was 70.5°. The ultimate analysis of these crystals showed the same composition as those obtained by the action of sulphurous anhydride on benzol.

I. 0.2500 grm. substance gave 0.6523 grm. CO_2, and 0.1117 grm. H_2O.

II. 0.1000 grm. substance gave 0.1160 grm. $BaSO_4$.

	I.	II.	Theory for $(C_6H_5)_2SO$.
C,	71.16	.....	71.286
H,	4.96	.....	4.950
S,	.....	15.93	15.843
O,	.....	.....	7.921
			100.000

From 50 grams of benzene and 16 grams of thionyl chloride we obtained 21 grams of the pure diphenyl sulphoxyde. The theoretical yield is a little more than 26 grams.

It is interesting to note that the diphenyl sulphoxyde fills a gap between the sulphide and sulphone just as phenyl-sulphinic acid is intermediate between the sulphydrate and the sulphonic acid.

$\left.\begin{matrix}C_6H_5\\C_6H_5\end{matrix}\right\}S$ Diphenyl Sulphide.

$\left.\begin{matrix}C_6H_5\\C_6H_5\end{matrix}\right\}SO$ Diphenyl Sulphoxyde.

$\left.\begin{matrix}C_6H_5\\C_6H_5\end{matrix}\right\}SO_2$ Diphenyl Sulphone.

$\left.\begin{matrix}C_6H_5\\H\end{matrix}\right\}S$ Phenyl Sulphydrate.

$\left.\begin{matrix}C_6H_5\\HO\end{matrix}\right\}SO$ Phenyl Sulphinic Acid.

$\left.\begin{matrix}C_6H_5\\HO\end{matrix}\right\}SO_2$ Phenyl Sulphonic Acid.

Nitration of the Diphenyl Sulphoxyde.

This operation appears to be difficult, since the nitric acid exerts an oxidizing influence on the diphenyl sulphoxyde.

The calculated quantities of diphenyl sulphoxyde and of sodium nitrate were dissolved in separate portions of concentrated sulphuric acid. The two solutions were then mixed together, and the mixture heated on a water-bath for two hours. The mixture was then poured into cold water and the resulting yellow precipitate, after washing, was dissolved in alcohol, and allowed to crystallize. By repeated fractional crystallization the result of the nitration was separated into three products:

First. Light yellow crystals, consisting of small rhombic plates, only slightly soluble in alcohol, easily soluble in glacial acetic acid. They had a melting-point of 163°, and we think they are the dinitro-sulpho-benzid described by Gericke.*

Second. Yellow indistinct microscopic crystals, melting at 116°, and readily soluble in cold alcohol, very soluble in ether, benzene,

* Gericke, Liebig's Annalen der Chemie, 100, 211.

glacial acetic acid, and CS_2. Ultimate analysis furnished the following data, showing that it is the dinitro compound of diphenyl-sulphoxyde.

I. 0.2504 grm. substance gave 0.4552 grm. CO_2, and 0.0691 grm. H_2O.

II. 0.2505 grm. substance gave 0.4532 grm. CO_2, and 0.0677 grm. H_2O.

III. 0.0500 grm. substance gave 0.0401 grm. $BaSO_4$.

IV. 0.2000 grm. substance gave 18 c. cm. nitrogen measured at 30°, and 765.6 m.m.

	I.	II.	III.	IV.	Theory for Dinitro-diphenyl-sulphoxyde. $(C_6H_4NO_2)_2SO$.
C, . . .	49.57	49.34	.....	.....	49.31
H, . . .	3.06	3.00	.....	.....	2.75
S, . . .	.....	.....	11.01	.....	10.95
N, . . .	.....	.....	.....	9.83	9.59
O, . . .	.....	.....	.....	.....	27.40
					100.00

The third product of the nitration of diphenyl sulphoxyde seems to be an oil at ordinary temperatures. We have not yet determined its composition or its properties.

We reserve for a future article the results of our work on other substitution derivatives of the diphenyl sulphoxyde, and also on some of its condensation products.

ORGANIC LABORATORY, SCHOOL OF MINES, COLUMBIA COLLEGE,
NEW YORK, November, 1886.

THE COLUMBIA COLLEGE CENTENNIAL.

"THE one hundredth anniversary of the revival and confirmation by the Legislature of the State of New York, of the Royal Charter granted in 1754," was observed with appropriate exercises in the Metropolitan Opera House, on the 13th of April, 1887.

At 9 o'clock A.M. the Alumni and undergraduates of the several

branches of the College met in the vicinity of the Columbia buildings, and marched in a body to the opera house. The Faculty and a large number of distinguished guests passed down the centre aisle to seats upon the stage, amid loud cheers from the undergraduates in the upper galleries, and the house was filled with Alumni and their friends, when Grand Marshal Woodford opened the exercises with a spirited introductory address.

We offer in the QUARTERLY a brief historical sketch, emanating from the College, and also the oration of the day, believing that both the substance and the subject of it warrant such a digression from the field in which our readers usually glean.

The celebration closed with a reception at the College in the evening. All the buildings were brilliantly lighted, and thrown open to the inspection of the Alumni and their friends, the School of Mines, with its interesting collections, competing very successfully for popularity with the Library Hall, where the reception proper occurred.—(EDITORS.)

HISTORICAL SKETCH OF COLUMBIA COLLEGE.

Columbia College was chartered, as King's College, on the 31st day of October, 1754. On the 17th of July preceding, in anticipation of the granting of the charter, the Rev. Dr. Samuel Johnson, first President of the College, began, in the vestry-room of the school-house belonging to the Trinity Church, the instruction of the first class, consisting of eight members. In May, 1760, the College moved into a building of its own. In 1763, a Grammar School was established, and in 1767 a School of Medicine. In April, 1776, the College buildings were taken for military purposes. For the eight years following, the College had but a fitful existence, and the first period of its history may be said to have closed with the military seizure in 1776. This first period was short but fruitful in the production of men who became conspicuous in the service of their country. "An eminent jurist has remarked 'that until the foundation of King's College, little more than twenty years before the Declaration of Independence, there were no seminaries within the Colony, in which any other than a very indifferent education could be procured. The influence of that institution on the literary character of the State was truly wonderful, for though the whole number of students educated in the College prior to 1775 was but one hundred, many of them attained to great dis-

tinction in their respective professions in public life.'" (*Moore's History of Columbia College.*) Among those who attained to distinction in public life were John Jay, Richard Harison, Egbert Benson, Robert R. Livingston, Gouverneur Morris and Alexander Hamilton.

In May, 1784, the Legislature of the State of New York passed an act, which changed the name of the College to Columbia College, and placed it under the control of a body entitled the "Regents of the University of the State of New York," which was to have also general charge of all the public institutions of learning in the State. The first student of the College under its new name and government was De Witt Clinton.

The control of the Regents proved to be but temporary, and on the 13th day of April, 1787, the Legislature repealed the act of 1784, revived and confirmed, with certain necessary alterations, the Royal Charter of 1754, decreed "that the College thereby established shall be henceforth called Columbia College," and placed it in charge of trustees of its own. It was the semi-centennial of this act which was celebrated in 1837. "On the 13th of April, 1837, was celebrated, with much solemnity, the semi-centennial anniversary of the reorganization of the College under trustees of its own. The Trustees, President, Professors, Alumni and Students of the College united in measures to give interest to the day. In the morning, at St. John's Chapel, an oration and a poem were delivered, before a numerous audience, by Alumni of the College previously appointed. Odes in several languages, composed and arranged to music for the occasion, were sung; there were suitable religious services and appropriate music, and honorary degrees were conferred on several distinguished gentlemen, selected by a committee specially appointed for that purpose. In the evening the College was decorated, illuminated, and thrown open for the reception and entertainment of a large number of invited guests." (*Moore's History.*)

It is the centennial of this act, under which, and by the administration of the body of trustees created thereby, the College has grown in power and usefulness, that is to be celebrated on the 13th of April, 1887. When the semi-centennial was celebrated, the College consisted of but one department—that now known as the School of Arts—and had in attendance 112 students. The centennial will find the College comprising five great Departments—

Arts, Mines, Law, Political Science, Medicine, and a Department of Graduate Instruction—and having in attendance more than 1500 students.

In 1857, twenty years after the semi-centennial, the College removed from its ancient quarters in College Place to its present site. At the same time, the curriculum was extended and the faculty enlarged. In 1858, a course of graduate instruction was begun, but in this the College was in advance of public sentiment and the project was temporarily abandoned after a year's trial. In that year, however, was established the present Law School, which has no superior in its sphere, and has educated more than three thousand lawyers. In 1860, the College of Physicians and Surgeons, which originally grew out of the Medical Department of the College, was adopted as, and now constitutes, the Medical School of Columbia College. In 1864, was established the School of Mines, which has grown until it now comprises within itself seven separate schools—Mining, Civil, and Sanitary Engineering, Chemistry, Metallurgy, Geology, and Architecture—and in all its several fields of activity occupies a commanding position. In 1880, a School of Political Science was established which is in successful operation and has attracted a large measure of public attention and regard. At the same time, the Department of Graduate Instruction was reopened and now has an assured future.

It is but fitting that the progress of the College for the last half century under the act of 1787, as briefly outlined above, should be celebrated in a manner, and with an enthusiasm, which should bear something of the same relation to the celebration in 1837 that the College of to-day bears to the College of 1837.

COLUMBIA COLLEGE, N. Y., January 31st, 1887.

ORDER OF EXERCISES.

1. PROCESSIONAL, from Lohengrin, ... Wagner.
ORCHESTRA.
2. PRAYER, ... BY THE CHAPLAIN OF THE COLLEGE.
3. INTRODUCTORY ADDRESS,
BY THE GRAND MARSHAL, STEWART L. WOODFORD, ESQ., CLASS OF 1854.
4. CHORALE: Awake my Soul, ... Wagner.
CHORUS AND ORCHESTRA.
5. ORATION, ... BY FREDERIC R. COUDERT, ESQ., CLASS OF 1850.
6. EASTER HYMN, . (Ancient).
LADIES' CHORUS.

7. POEM, . . . BY REV. GEORGE LANSING TAYLOR, D.D., CLASS OF 1861.
8. MARCH, from Lenore Symphony, ... Raff.
ORCHESTRA.
9. CONFERRING OF DEGREES, . . . BY THE PRESIDENT OF THE COLLEGE.
10. DOXOLOGY: Old Hundred.
11. BENEDICTION, ... BY THE BISHOP OF THE DIOCESE.
12. JUBILEE OVERTURE, ... Weber.
ORCHESTRA.

ORATION.

BY FREDERIC R. COUDERT, ESQ., CLASS OF 1850.

The brief period of a single century's life will not permit the most earnest and devoted of Columbia's children to claim much for her on the score of age. Time has not woven its ivy about her walls, nor is her record made beautiful by the lights and shadows of poetical tradition. The imagination of those who study her history finds little in mere lapse of time to arouse enthusiasm or to justify that license of laudation which the uncertainties of remote antiquity make plausible and alluring.

Columbia has thus far barely passed the age of man; there are men now living—there certainly is one man living—who may count as many years of life as she. The wise and learned Chevreuil celebrated his centennial a year ago with all the vigor and zest of youth. So long as he shall live to taunt us with this coincidence, we must be content to consider ourselves scarcely adolescent, even were we not informed that the University of Bologna proposes to celebrate its 800th anniversary in 1888.

But men, as nations, do not always develop by the arbitrary standard of numbered years. Nor, as was said of Marcellus' fame, is their glory like that of the tree which grows by the unheeded lapse of time. There are periods of history when events long prepared burst into sudden life by a single explosion, as certain plants that flower at long intervals, passing by no perceptible transition from apparent barrenness to the height of perfect fruition. Minds mature under the influence of political or moral convulsions without reference to the ordinary requirements of time. Youth steps over the gradations that usually separate it from age and its experience, at a bound.

The end of the last century was one of those seasons of intense and feverish activity that spurned the slow processes of gradual development. The leaders of the world of thought and of action

were scarcely out of their boyhood. When the sound of the booming guns that announced the victory of Austerlitz, struck Pitt as though he had received a bullet in his breast, he was but twenty-six; Robespierre's brief career, so full of mischievous and unbounded power, ended at thirty-six; Napoleon had captured fortune and held her a hostage twenty years when, at forty-six, his life ended for all purposes, except to point a conventional moral. Here in America, the same forces were at work. Men scorned the maturity that came by slow degrees. Revolution and war would not brook the restraints of time. The natural tendency of the human mind to reject authority and to rebel against the tyranny of precedent had been strengthened and developed by the new agencies which came under its command. The press furnished to every new idea and to every new scheme of revolution, social, political, and religious, the fulcrum that Archimedes longed for in vain.

The generation of men that stood by Columbia's cradle was fast learning to take nothing upon faith, and to trust but little to the sanctions of the past. Skepticism, as defined and extolled by Buckle, became the pervading quality of modern thought. The seeds sown by the philosophers and essayist of that period soon bore their fruit. Those pioneers in the sphere of new moral forces and methods left behind them a legion of followers. As we to-day look back at their first efforts, we watch with admiration or dismay, as our education or taste may prompt, their bold assaults upon the bulwarks of ancient opinion.

The sneer of Voltaire had been so potent for destruction that it now marks one of the transition places in history. Hugo, in his delirious admiration of the arch-skeptic, has ventured, with blasphemous exaggeration, to couple the cynic's mocking smile with the tear that the Divine Master shed upon the creatures that He loved and redeemed. The whole social and political fabric was to be remodeled for the benefit of mankind, and Utopia was to become a reality of everyday life. The divine right of kings, so rudely assaulted in the person of Charles I., received its death blow when Louis XVI., the most amiable of monarchs, laid his head upon the block after helping the rebel colonies to defeat their own king. Old landmarks were torn up before the new ones were determined upon, and the world of Europe moved for a season, as a ship whose

compass is taken out for repairs while the helpless pilot, helm in hand, waits for the precious counsellor to be returned.

Then, while men were groping for new lights, and reacting against the law of force which had, for a season, stayed the destructive current that threatened to sweep away the ancient order of established right, the new theory of universal knowledge was broached, and all the agencies by which the mind could be fed and the intellect developed, were sought for, tested, and adopted with almost feverish haste. Wise men knew, and others felt, that the new departure would be a mockery if the old methods remained, while the old sanctions were gone; States without kings, churches without bishops, rulers without power, forms of authority without its substance, the right to sneer at all things, to disbelieve all things, to advocate all things, must be guarded by a new force, and that was decided to be knowledge.

And thus it was that when Columbia came upon the scene she was confronted with new conditions. The drowsy and happy life of well-endowed seminaries was gone. Caps and gowns and stall-fed dignitaries might still exist as pleasing though obsolete symptoms of prosperous and scholarly ease, but the life must be a new one, and the standard, the test, the result, must be of a different complexion. The pale scholar whose elegant idleness had been sufficient for himself and for his day, must be made of sterner stuff and more durable material. Men must be sent out to meet the world, the new world; the great harvest was white for the reaper, but he must be strong and active and brave, for those who had been the last were to be the first. All who wanted to be great, thirsted for knowledge, because they were told that knowledge was power, and that the one through the other was within the grasp of all.

Knowledge is Power.

Has not this shibboleth been used so long that prescription challenges criticism? It has passed from generation to generation; from wise fathers to eager sons, with the stamp of the real coin and the ring of the true metal. Whatever else men have disagreed upon in giving worldly counsel to the rising youth, they have agreed that knowledge is power; that knowledge is the magic wand that points to the concealed treasure; that it gives wings to him who pursues fleeting fortune; strength to the weak; wealth

to the poor, and opens untold possibilities of greatness to its fortunate possessor. Aladdin's lamp was but a parable of what knowledge, once mastered, might do for its possessor. The genie that did the bidding of its master was not a more obedient slave, nor more potent than the intangible indefinable abstraction that we call knowledge. And yet even now we might venture to ask if this be literally, or at all, true. The epigrammatic precept bears the subscription of a greater one than Cæsar; that is the common opinion of men. But do all men mean what this really implies? Have wise and thoughtful teachers ever intended to convey to those who look up to them as counsellors and friends, that with knowledge alone, the paths of life were to be cleared and the prizes secured? Surely not. For mere knowledge of itself and by itself is not power. What were Orlando's sword without Orlando to wield it, or Mercury's wand without Mercury, or Milton's pen without Milton? In truth many, if not most, of the great achievements of the world, have been effected without knowledge, or with knowledge as a secondary adjunct. Charlemagne conquered Europe, and held in his rude hand the power of a dozen modern kings. It was not knowledge that drove the Saracens in bloody rout from Europe, nor knowledge that helped the modest maid of Orleans to smite her country's foes with the vigor of a Homeric hero; nor was it knowledge that stood by the barbarian leader of Gaul or of Germany when he held Rome's legions at bay; nor was it knowledge that made Leonidas and Thermopylæ immortal. It was not knowledge that led the early Christians to brave the wild beast in the Coliseum, and smiling to shed their precious blood for a testimony to their faith, and yet they conquered the world. The rude monk who stirred the nations of his day to leave home and friends to fight the Saracens, had no knowledge that would earn that name to-day, and yet the fable of Cadmus and the dragon's teeth was more than realized by him and in his person.

Knowledge of itself is no more available to achieve success than the wire is useful while it awaits the electric current that will give it life, and with it laugh at time and space. Of what use is the mammoth engine that may do the work of a thousand men, if the life is not made to animate the sluggish mass by the agency of fuel and steam? The nickel coin that buys a loaf, or a newspaper, or a ride, has in it more real power than tons of hidden gold that lie concealed in the depths of a western mountain. Knowledge, of

itself, does nothing. It is the man behind it who enables it to work, and draw, and fight, and write, and conquer. How would the knowledge that Columbus had have helped the world, if the spirit had not leavened it and the tenacious will fought its way through the obstacles that tried, but never wearied, the brave soul?

Where did knowledge alone ever penetrate the darkness of human life, or quicken the pulse, or drive the will, or control the passions of men? The mediæval monk, who prayed and toiled from early dawn, amassed a wealth of knowledge that would have enriched the world, but what availed it until a man was found to catch his words and imprison his thoughts, and clothe them in type so that they might be echoed and re-echoed through the ages? The poet never said, as he is daily made to say, that the "Pen is mightier than the Sword," but he did say that:

> "Beneath the rule of men entirely great,
> The pen is mightier than the sword."

The mightiest sword of our generation was Grant's, and the mightiest pen was Lincoln's; the one wrought its way to Appomattox and the other wrote the great proclamation of freedom. Was it knowledge that did all these things, or was it the faith, the courage, the manhood, the love of country? With these the man is surely great, but without them the learning of all the schools will lie inert, useless, like the miser's treasure; great only in wasted potentialities.

If this be true, if history and our daily experience have taught it, then let the lesson of the centuries be felt in our life. Let our children know and feel that men—not more than armies—are efficient to perform their allotted functions, because they have a cumbersome mass of impedimenta to accompany them, but rather that it is the ability to use the tools that will give them the power that they seek. Teach them that the man is more than the instrument; that the spirit is the real and the best part of the man. Knowledge is the whetstone that sharpens the blade, the fire that tempers it, the monitor that teaches its use. Themistocles might not have been Themistocles if he had been born and bred among the Seriphians, but a whole colony of Seriphians transplanted into Athens and taught in the Portico might never produce a Themistocles. The mere man, the *homo*, is sure to follow, for he is made to follow; the *vir* must lead, for *he* is made to lead, and will lead, whatever his birth, or condition, or surroundings.

FAITH.

The great complaint of thinking men to-day is that the rising generation, into whose hands the direction of public affairs must soon fall, has lost or is losing its faith.

If men have really lost the faith which cemented modern society, or if they are in danger of losing it, then is the world face to face with a new peril. Even those who affect to view the question with philosophical indifference, cannot close their eyes to the fact that a great void will then be made that something must be found to fill. The scornful concession that "religion is necessary to the government of the lower classes" might have some force and bring with it some comfort when the "lower classes" were willing to continue in their debased condition. But where are the lower classes in this age and country of ours? Education, opportunity, precedent, combine to stimulate the great mass of our people to seek for improvement and elevation. The time has long gone by when the son humbly accepted the father's place, and, with traditional humility, was content to accept transmitted servitude.

Carlyle tells us of the hard-worked peasantry of France who beat the ponds at night lest the croaking of the frogs should disturb the lord of the manor as he rested in his castle, but *now*, the peasant's son owns the castle. The humble soldier was content to fight and die unhonored and unknown that the leader who, by virtue of his birth, held a prescriptive right to the glory which *he* helped to earn, might earn fresh titles, but the rude soldier now carries the marshal's baton in his knapsack; *he* is himself the ancestor whose brave deeds take the place of parchment records. The many sowed that the few might reap, and both classes considered this a providential arrangement which it would be impious to disturb. The hope of compensation in a future life satisfied the longings and kept down the rebellious spirit. Men were willing to suffer, and strong to endure, while they held the belief that their tribulations would be exchanged for an infinite reward that the language of man was too poor to define or to depict. The beatitudes promised him were far beyond the immediate and finite blessings that even the richest and proudest of his masters could boast, but they were real to him, and he rejoiced in them because he saw them through the glass of faith. How else, and why else, would he have borne the burden of the day and the heat, when by the mere raising of his arm he could have shattered the whole system?

God made the stars, says Lacordaire, that men might look up. But if men cease to look up, and if faith is dying or dead, what ligament has the wit of man devised to take its place and to hold society together? What Œdipus will solve the riddle? What Æsop will have an answer for every new problem? What prophet of the new dispensation will lead men captive to the promised land, as Orpheus with his magic lyre led the listening oaks that rashly followed him? For whatever view we may take of this matter, we all know that it is a question that must be met. If the alarm sounded from pulpit and press and rostra has a true note of warning in it, then the college of to-day has to deal and grapple with difficulties that can be decided by no precedent.

A society of men without religion would present a new spectacle and must live, if at all, upon some principle other than that which has thus far made the strong currents of life flow through its members. The morality and virtue of modern society are the practical forms of Christian teaching, not the arbitrary formulas of philosophers, nor the emanations of conventional rules. Zeno and Seneca may fill the student's mind with delight, but they have never been practical factors in forming the morals of men. Nor has the world ever so sorely needed the power and assistance of the religious motive and idea, for never before has the freedom of individual action and the liberty of opinion been so nearly absolute. The day of coerced obedience to sacred law has gone by forever. Blasphemy may be ranked among the offences that are retained on the statute book, though long since obsolete, but it is, nevertheless, as free to preach its doctrine of destruction as the teachers of Divine truth to proclaim their own. While these discourse at stated times of the weighty topics that it is their calling to expound, others, equally eloquent, perhaps, and equally earnest, denounce these doctrines as the superannuated remnants of a decayed or imperfect civilization. But the spirit of our people will not brook the only remedies that past generations could devise to prevent assaults upon the faith that was thought as essential to the security of the social order, as the foundation of the building is to the security of the edifice.

While men differed as to the form of doctrine, and as to the doctrine itself, while they fought for a diphthong and shed human blood for a difference in a reading, while they were divided among persecutors and persecuted, executioners and victims, as though

the crime of non-conformity to this formulation or that, were the weightiest that men could perpetrate, there was the one common belief in the Higher Power. Men were cruel because they were earnest, and they suffered because they were convinced.

Faith of some kind was the mainspring of society from the time that ancient Rome fell to pieces because her faith, false and hollow as it was, had gone. If, perchance, isolated instances of rebellion against the general belief showed themselves, the strong arm of temporal power dealt swiftly and surely with the enemy of society. Not the policy and teachings of Church and State alone combined to guard the sacred temple from desecration, but the common opinion of men joined the two and made them irresistible. When kings founded their claim upon a divine right, the traitor was guilty of a double crime, and no penalty could be too cruel to punish him and to deter others from like violations. To raise one's hand against God's anointed, was the extreme point which the depravity of man could reach, and was, therefore, defined and treated as the embodiment of all crimes.

And then, too, the very manifestations of nature, in which the Creator showed his power, reinforced the natural obedience of men to the Divine law. The lesson of the earthquake, of the comet, of the cyclone, or of the eclipse, came upon them as the direct emanation of God's wrath, or the living proof of His warning. Horace was not the only one who turned from his careless and infrequent devotions to more pious practices, when Jove suddenly and without warning clouds drove his thundering horses and swift chariot through the clear vault of Heaven. Perhaps the ease and pleasure-loving poet was not so ready a victim to the terror which he describes, as he affects, but if he was not, others were, long after the pagan temples had lost their honor. Great convulsions were always followed by redoubled zeal, and no sermon that was ever preached by human lips reached the hearts and stimulated the devout terrors of men as the tidal wave that swept away 20,000 human beings in the twinkling of an eye. But Horace would not now leave his Falernian, nor the pleasant banks of the cool stream that he loved, because of a comet, or an eclipse, or even an earthquake, unless the rumbling menace were near enough to reach his ears; none of these heavenly portents would interrupt the ode to Lydia, or to Glycera. The preacher now knows, and the hearer knows that the phenomena which were looked on as

threats of coming catastrophe, are the obedient movements of the slaves to a great law.

All this touches us more nearly than any other community. No school boy need be told that in our Republic, the Government, belonging as it does to numbers, must be based upon the best qualities of men; that no society can count upon the future which, by its very nature, rests upon the caprice of ignorant, vicious and accidental rulers. The grave experiment of subjecting the fortunes and existence of a nation of 100 millions to the probability that the majority will be fit to rule itself and the minority, is soon to be made. We all cry out that by education alone, may we solve the difficulties and problems that beset us. Even Montesquieu understood this more than a century ago: "The Republican form of Government," he says, "is one that peculiarly needs the power of education. Fear in despotic governments is born of threats and punishments, but political virtue requires renunciation of itself, which is always a painful act." What is the education best adapted to do this? How shall the generation that is pushing forward to seize the helm and control the ship, be taught to perform its duties? Once, within a quarter of a century, that ship was sorely beset. The lover of his country might well grow pale and cry out with patriotic anguish: *O navis, referent in mare te novi Fluctus! O quid agis?* For her masts were broken by the storm, and her main yards groaned, and her keel could scarcely support the impetuosity of the waters. The peril is different now, and still remote. The great questions that follow large accumulations of wealth, class differences, real grievances, as well as fancied wrongs, the multiform varieties of the struggle for life, must be met, and with one, the only panacea, education. If it be really education; if it be that which draws out all that is good in men, and smothers what is bad, our panacea will do its work, and we need fear no evil. Let us have a care lest we be forced to exclaim, as the poet just quoted:

Non Di quos iterum pressa voces malo.

Sore pressed with evil, you have no Gods, whom you may again invoke.

THE UNIVERSITY.

These reflections naturally lead us to consider the question of the American University,—a living practical one, full of momentous meaning for the future of our country.

I shall hardly undertake to define in a paragraph, the university that is, or ought to be, the ideal of our day and generation.

The eminent orator and scholar who made Harvard's recent celebration memorable, asked the question, "What is a university?" and answered it by quoting himself as having said thirty years before that, "A university is a place where nothing useful is taught, but a university is possible only where a man may get his livelihood by digging Sanskrit roots."

I am not unconscious of the boldness that might be imputed to me should I attempt to criticise this epigrammatic expression of opinion from one of the leaders of our intellectual world, but I do not hesitate to say that if the university of the future is to be an asylum for incapables, or a home for sophists, or a shelter for unprofitable servants, the sooner the truth is ascertained, the better it will be for our people.

Even so respectable an occupation as the study of Sanskrit roots will never suffice to make the university a real institution in America, if its main objective point is the inculcation of useless knowledge. Whether knowledge can ever be useless might here be questioned, but I assume that the meaning intended is, that no learning of the practical, active and vigorous order is to be admitted within the portals of this ideal establishment.

If I could venture to give a definition of my own I should, on the contrary, proclaim that the true university is that which teaches nothing that is useless, and everything that is useful and good. That its aim should be to form a class of men who, by their training, moral and intellectual, would be the model men of the country, in the government of which they might be expected to take a large and useful part. I would be bold enough to say, that the real university should concern itself in ripening useful talents, in eliminating useless and idle theories. Law, medicine, theology, literature —surely all these things, in all their branches and off-shoots, form useful subjects to the student. To elevate the standard of all the professions; to purify the taste and ennoble the pursuits of study-loving men; to arm these with the weapons, offensive and defensive, which experience has proved to be available in the battle of public or private life—these are aims which may well encourage the founders of our ideal university.

The college of yesterday, and the high school that preceded it, have and must have their mission, but an ever-broadening field opens before us with increasing responsibilities and possibilities.

I know of no people who were ever yet successfully governed without a class of men by birth, or training, or education, better fitted than other men to assume and perform the functions of government. Whether it be an army, or clergy, or nobility, or a free press, or a fearless bar, or a learned and honest bench, there must be somewhere a reserved corps of men willing, ready and able to make, administer and enforce the laws. No monarch ever felt secure without such coadjutors to sustain, none ever felt safe with such to oppose his power. The Prætorian Cohorts made and unmade emperors at their will, because they represented the dominant idea of force incarnated in themselves, and used it as they would. When morals were at their lowest ebb the populace, with no guide but its caprice, raised and tore down the purpled puppets who gave or refused the *panem et circenses* that it clamored for and refused to clamor for in vain. In England, the barons and the vassals held by them, in their marvellous system of feudalism, furnished the stay and support which kingly power required. And as increasing civilization modified this state of things, the reign of the sword was mitigated by the advent of the intellectual element, and they became great who could sway the multitude by their voice or by their pen.

The efforts of such men became concentrated into a focus and a parliament arose, which though obedient at times to a strong will, soon learned its power, increased it, and kept it, and now holds within its grasp absolute omnipotence, bounded only by its own self-denial. France, even in the gorgeous period of Louis XIV., was led by a brilliant aristocracy of soldiers and a growing class of writers who spread their empire slowly but surely until they too, made and unmade kingdoms. And if the great Napoleon fell in a day, and was swept to a barren rock to die, was it not because the only chosen body that *he* had to sustain him went down with him at Waterloo, while the intellectual force of the age was his foe?

Where, then, in America shall we find that class of leaders to whom the thinking and working mass of our people may look with confidence and just expectation? Aristocracy, in its old and conventional sense, conveys but an empty and meaningless sound —yet is it not of the very essence of democracy that the best men should stand at the front as the guides and chosen leaders of the people? Political questions of great moment cannot be decided

by public clamor in a market place. The rule of the people means that the people shall choose its own instruments to do the work of governing; the quality of that work shall depend upon the temper and quality of those instruments. From corrupt and polluted sources no good may come; nor can sweet and bitter water flow from the same orifice. These chosen men must be strong and brave and wise. If education be the only means by which the best that is in men may be educed, then should it be the crowning glory of our ideal college so to deal with those who enter its doors that they shall leave full-armed and equipped, strong in faith and in hope, self-reliant, not filled with doubts and armed with negations, but positive, large, healthy-minded men. We have our schools of law, of medicine, of theology, of science, shall we not have the culmination of the school system from which shall emerge the man—full, rounded and complete?

The idea is not a new one. Plato discussed the subject many centuries ago. "Is your meaning," asks Protagoras of Socrates, "that you teach the art of politics, and that you promise to make men good citizens?"

"That, Socrates, is exactly the profession which I make."

"Then," I said, "you do, indeed, profess a noble art."

It may be unnecessary to add that Socrates and Protagoras were not speaking of that science which is popularly known as "practical" politics, and which has other objective points than the making of good citizens.

Athletics.

The new departure in Athletics deserves a word of commendation and of caution. The exploits of our Columbians in this field of College Education need not be here rehearsed, but it may be said, without undue exultation, that they have proved that urbanity and physical development are not inconsistent. A man may be a gentleman and win the prizes, even at football, although I fancy that the test is as severe as human nature can endure. The time was when a youth was noble who could fling the discus beyond the line, and it was a bad omen for his manhood when he gave up the exercises without which that manhood was incomplete.

Neque jam livida gestat armis
Brachia, Saepe disco,
Saepe trans finem jaculo nobilis expedito.

There is a classical flavor about these manly exercises that detracts nothing from their excellence. A sound body and a sound mind are the true watchwords of real training: the Gymnasium that cared for the body and the mind, was the true ideal of an Educational Seminary. But is there not a danger that the subdivision of labor, which is at the bottom of modern progress, may be carried to undue length in the distribution of college duties? The sound body and the sound mind should be united in the same person; not divided among several. A trained corps of athletes would hardly reward the college that produced them, if the abnormal development of the biceps or thoracic muscles had been gained at the expense of other acquisitions. The doctrine of averages would not comfort us if the physical excellence were all on one side and the mental superiority on the other. Is there no danger that emulation and an honorable anxiety to uphold the college standard may lead to that result? Whether it be so or not, Time will determine; meanwhile we shall exult in the honorable victories and honorable defeats which the future may have in store for us. Cato Maior puts a question which the young athlete would answer, I think, with no hesitation, but not as that old and self-satisfied philosopher would have liked: "Milo is said to have gone around the Olympic Course carrying an ox on his back; which would you prefer, to have this strength of body, or to be gifted with the intellectual powers of Pythagoras?" Where would Pythagoras stand on a show of hands? Even a respectable minority would be a triumph which the father of metempsychosis could hardly expect to secure.

But the bodily strength of Milo, and the intellectual vigor of Pythagoras need not be rival candidates for supremacy; rather let the harmonious development of both, growing in close sympathy and mutual support ripen into the best fruit which the highest culture may produce.

When, as Milton expressed it, Athens was the eye of Greece, and when Greece was the leader, model, teacher of the world, athletic exercises were not the sports of idle men, nor the resource of those who sought to make up in physical prowess what they lacked in mental attainments. But the noblest and the best devoted themselves to those pursuits and strove for the glorious palm of victory. Poets, philosophers and orators strove to gain the crown at the national games. Plato himself did not scorn, it

is said, to enter the arena as a candidate for the honors there to be earned.

Pindar's grandest odes celebrate the triumphs to be won in these contests for supremacy, triumphs which appealed alike to the admiration and the envy of all. Far above the ordinary pursuits of the citizen, far beyond the other prizes which might make immortal renown, was the glory of the victor at the Isthmian and Olympic games.

The tame pursuits which bring in daily bread and homely comfort were no fit subject for the poet whose imagination had been kindled by the fire of these themes.

"The various rewards proposed for their works are pleasing to various men," says Pindar; "both to the shepherd and to the ploughman, and to the fowler, and to him unto whom the sea gives support, and each one exerts himself to ward off direful hunger from his stomach. But he who, in games or in battle bears off beauteous glory, receives, by being praised, the highest gain, the choice speech of citizens and strangers."

This will seem a poetical extravagance of speech in our day and generation, but the glowing language of these immortal writers will show that contempt of the body, which has too long characterized the scholar, finds no warrant in the teachings of men who were giants in their days and who are giants still.

Electives and the Classics.

Who shall rule our colleges is a question that agitates the student mind to no small extent, and leaves the higher authorities not wholly undisturbed. That the imperative mood must be sparingly used, is becoming a canon of well settled college discipline; whether, and how far, occasional recourse to that mood in a softened and mitigated form may be had, is still debated, chiefly outside of Columbia.

Those who have read Cicero de Senectute, and have learned from him that the seniors, or older men, were the ones who preserved and maintained the integrity of states against the rash and reckless attacks of the juniors, will not readily concede that the choice of intellectual food should be left to those who have the least knowledge on the subject: especially to those who are actuated by the most universal of nature's instincts, the desire to shorten

the hours and mitigate the asperities of a day's work. *Temeritas est videlicet florentis ætatis, prudentia senescentis.* How long will this prudence of old age withstand the attacks of rash and vigorous youth? Has not the white flag of surrender already shown itself on the citadel? If the Act of abdication is not already signed, the Bill of Rights and the Magna Charta have been delivered, and the oppressed youth of our sister institutions, at least, are near their enfranchisement, and free to play the dangerous game of liberty.

Yet it may be urged without intending offence to the growing citizen, that a deep-seated and genuine reluctance to study Greek, assuming it to exist, does not necessarily imply genius in any other direction. A student may honestly feel that Melpomene never presided at his birth, and that he was intended for other victories than those which devotion to the Muses may secure, and yet be unable to select with judgment the pursuit for which he is best adapted. This has probably been the cry since the alphabet was taught. Vocations to do are rare, but vocations not to do are common. True genius sends its arrow to the mark with an unerring instinct which painstaking mediocrity may never emulate, but it cannot expect to make its rules for the general government of mankind. The law of averages fixes in advance the number of marriages, except, according to Buckle, when disturbed by fluctuations in the corn market; so it does the number of suicides and misdirected letters; may that law not govern us wisely in matters connected with education?

The experience of years—nay, of centuries—may not be disregarded or set aside in subservience to new theories, the value of which is still unproven. How to discipline the mind of youth and give it the proper food is not a matter to be abandoned to chance, nor decided upon any other than well-considered grounds. The kind father will not give a stone to the child who asks for bread, but neither will he give him a stone when he asks for a stone instead of bread, nor will he let him dictate the material of which the bread, whether to feed his body or his soul, shall be compounded.

It may be that in the curriculum of our modern colleges too much attention is devoted to a particular study, and that in the whirl of our constantly increasing activities we might with profit cling with less tenacity to old traditions. It may be that the Greek and Latin languages, and literature, and mathematics should be jettisoned in order that the rest of the cargo may be saved; but

will the residue be worth the saving? Volumes have been written on either side of this question, which, I fancy, would never have reached the dignity of a question had not the overloaded college curriculum, groaning, creaking and strained, cried loudly for relief.

Heretofore, familiarity with the models of ancient learning, literature and eloquence was the crowning excellence of a generous education. No orator, poet or historian could expect to scale his Olympus who had not been inspired by the ever potent voice of Athens and of Rome. Each man was great as he approached and resembled the masters who were as secure in their supremacy as the statue of the Grecian Venus in the Louvre. There she stands and smiles her defiance after all the centuries, challenging the world to match her in her mutilated beauty—a landmark, as it were, on the very verge of human perfection, fixing the limits beyond which the genius of man has never gone and may never go. *Huc usque venies*—thus far and no farther shalt thou come—she seems to say.

The deepest thinkers and the wisest men—leaders of thought and of action—deemed the time well employed which they gave to the contemplation of these masterpieces. In the beauty of their conceptions, in the chastity of their style, in the art which marked their productions, written or spoken, the inspiration of these models was to be traced. The noblest periods that ever shook the Halls of Westminster were the echoes of the hushed yet living voices of antiquity; they came from patriots and scholars who, with becoming gratitude, acknowledged the greatness of the obligation. So it has been in our own day and with our own leaders. Our most honored magistrates and most eloquent advocates have drawn freely from these fountains. The Erskine of America, Rufus Choate, like the Erskine of England, exulted in the possession of the treasures that he had discovered while seeking the fountains of learning and art. Webster, the master of our masters, in his matchless oratory blessed and thanked the Alma Mater that had conducted him to the glorious land whence he had come back laden with untold wealth. At all times, in all countries, where the charms and refining influence of scholarly pursuits have been prized as they deserved to be, these noble studies expanded, enriched and delighted the minds that were capable of feeling their spell. Their creative power and influence are as clearly traceable in the intellectual productions of modern times as the influence of Greek art

in the architecture and sculpture of the centuries that have followed the fall of Athens. No statute of limitations can bar the operation of such influences; true genius works for no time or country, but with marvellous reproduction re-creates itself for the benefit of all ages and all men.

Early History of the College.

The history of the college, I have said, lacks those elements of poetry which are born of twilight and imagination.

The inscription on the first stone laid by King's College—the first in the province of New York—bears the recent date of 1755. The college is only some twenty years older than the nation. Its beginnings were humble, times were stormy and funds were scant.

The first president of record was the Rev. Dr. Samuel Johnson, who left his quiet home at Stratford to take the presidency of the new college and to receive therefor the not very munificent salary of £250 per annum. We may infer from this that he was not actuated by mercenary motives, even when we couple the actual stipend proposed and accepted with the suggestion made by the trustees that the Vestry of Trinity Church might thereafter make a reasonable addition to the sum named.

The most conspicuous service rendered by the learned doctor appears to have been to devise the college seal, the principal feature of which embodies a prophetic vision of the future, for he pictures a lady sitting on a throne, or chair, with several children at her knees, to represent the pupils. It is to the credit of Columbia that not only in this allegorical form does she recognize the true function of woman in the cause of education, but that she has practically entered upon the duty of fitting woman for the quality of teacher by first permitting her to be a pupil.

The learned doctor's labors were considerably interfered with, and his peace of mind disturbed by a great, and, no doubt, fully justified, apprehension of the small-pox, for in November of 1757, he fled to the County of Westchester, where he remained about a year, to allow that dreadful scourge to disappear, and in '59 he was again compelled to fly and remain absent six months. But as others continued in charge of the college its quiet pursuits were uninterrupted, and in 1758 the first commencement was held, at which the degree of Bachelor of Arts was conferred on eight students. Three of these had been educated at Philadelphia, or

at Princeton, but desired, apparently, to start in the world with the eclat of a diploma from King's College. Only two young gentlemen were admitted to the degree of Bachelor of Arts in the following year; one of whom had already received at Princeton such education as that college at that time could bestow; the other being the only one out of six admitted in '55, who had persevered to the end. The minute care with which the college even then interested itself in its growing children, is manifested by the very frank expressions which are found in the matricula of the college respecting those who entered the Freshman class of that year ('55). One of them appears from these notes, in the third year to have gone to Philadelphia College, presumably because the standard of King's College was too high, or the application required too severe. Another, made of sterner stuff, about the middle of the second year, went into the army; another, after the third year, considering, no doubt, that he had acquired all the knowledge that commercial pursuits demanded, went to merchandise; of the fourth, it is said that after about two years he went to privateering—as it were a special course of commercial training; and of the fifth, it is said that after three years, he went to nothing.

But, neither the small-pox, nor a lack of students, nor scarcity of funds, interfered with the growing academy. At all times, and from the very beginning, its aims were of the highest, and it does not seem to be an exaggeration to state here, that to-day in its full development, and in the fruition of its efforts and labors, Columbia College has simply carried out the promises of its early founders.

It may be observed that one of the advantages incident upon the late birth of this institution, has been to free it from the trammels and embarrassments which its predecessors have had to contend against. There was nothing in the charter requiring Columbia to exert itself in behalf of the Indians, nor to support a learned corps of missionaries to reclaim them from their hopelessly wild and dissolute habits.

It is a striking commentary upon the ready response that King's College found in the city of New York, that some of the most distinguished men of the Revolutionary period were then among its students. The Freshman class of 1762 was composed of John Jay, Egbert Benson, Robert R. Livingston, and many other men whose record is a part of our history.

It did seem, at one time, as though Fortune had removed the

bandage from her eyes and intended to smile upon the deserving and struggling college. A grant of 24,000 acres of land was made, but as it turned out to be in debatable territory, which the State of New York abandoned to Vermont for the sum of $30,000, which sum the State retained, no benefit ever accrued from this apparently munificent donation.

Dr. Johnson's successor, the Rev. Dr. Cooper, was destined to undergo even more serious tribulations than those encountered by his predecessor. Although we do not hear that he was driven abroad by small-pox, it is certain that the even tenor of his life was greatly disturbed by the premonitory symptoms of the explosion of 1776. His proclivities were, naturally enough, in favor of the British government, and it is said that in a literary skirmish between himself and an anonymous adversary he was badly worsted, which no one will wonder at who is informed that the pen of that adversary was held by Alexander Hamilton, then a student in one of the younger classes. Napoleon is reported to have sought to comfort an Austrian officer who bitterly bewailed his fate, after the French victory of Austerlitz, by saying: "Young man, you need not be mortified at being defeated by *me*;" and we will think none the less of the learned doctor because his steel was not equal to that of the boy-champion in the cause of liberty.

But if it was natural that Dr. Cooper should maintain and express his feelings of loyalty to the crown, it was equally natural and to be expected that the expression of those feelings should be viewed with much resentment by those about him. Only one year before the Declaration of Independence was signed, a letter was addressed to him and a few other obnoxious, but probably very harmless gentlemen, ascribing to them all the desolation which was in part then felt and in part anticipated by the residents of New York. This letter, fortunately, closed with good advice, and still more fortunately, the doctor was wise enough to follow it: "Fly for your lives, or anticipate your doom by becoming your own executioners." Signed, "Three Millions." The Doctor, availing himself of the choice thus generously left him by the signer or signers of this letter, adopted the first alternative, and escaped in the dead of night, only half dressed, over the college fence.

After adventures, or misadventures, which it is not my purpose to relate, he succeeded in reaching his native country, where he

spent the remainder of his life among stanch and sturdy loyalists, far from the threats and execration of unreasonable rebels.

The college was forcibly seized in 1776, and the record of that year shows that the confusion which prevailed in every part of the country, effectually suppressed every literary pursuit.

In 1784 the Legislature of New York granted certain privileges to the theretofore called King's College, and three years after the act was passed, under which it received its new life and under whose beneficent influence it has since pursued its prosperous career.

In 1820 the college possessed the inestimable privilege of seeing most of her offices filled by her own children; Professors M'Vickar, Moore, Anthon and Renwick were all reared by her; their names are household words, and the history of the college from that day forward is one of unbroken progress. What she has done, where she stands, and what success she has met with, we all know. The twenty-four students who constituted the number within her walls when Dr. Johnson left, have now expanded to sixteen hundred.

In every walk of life her graduates have done their State and country honor. From the time when John Jay, Alexander Hamilton and De Witt Clinton occupied the highest positions in the councils of the nation, on the bench, or in the Senate, her children have been conspicuous in the government of our country, state and city. The record of illustrious names to which she can point would be as long and as tedious as Homer's catalogue of the ships that carried the Greeks to Troy. An alumnus was Mayor of New York one hundred years ago, another is Mayor to-day. The chief adviser of the city, the attorney for the people, the President of the Board of Aldermen, Judges on the bench, members of the Legislature and of Congress, in all positions of life, we find them, honored and respected public servants. If the tree may be known by its fruits, then may Columbia feel proud of her nobility, of her service in the past, of her promise of future usefulness.

And why should she not be a leader among the first? Born and raised in the Imperial City of the Continent, she has grown with its growth, and flourished with its prosperity. With the vivifying influence of a vast and active population to keep her from stagnating into decorous ease, with the growing affluence which requires corresponding culture, with a generous emulation to out-

strip her brilliant and friendly rivals, why should not Columbia justify the best aspirations of her founders? There is no limit to her possibilities of good, provided she may ever count upon the loyal and loving adherence of her children. If that does not fail her the measure of her prosperity will be filled. The hardening processes of our modern life; the heat of competition in the arduous struggle for existence, are apt to deaden sentiment by repressing its manifestations. But as no man need blush because his heart beats high and his speech grows warm for his country, his home or his faith, so need he never blush because a tender chord binds him to the mother that made him what he is. True sentiment is not weakness; it is strength. It makes fragrant the commonplaces of life; it throws a purple mantle over the humblest occupation, and keeps alive the sacred fires in the temple of pure and genuine manhood.

ADDITIONS TO THE COLUMBIA COLLEGE LIBRARY IN THE DEPARTMENT OF NATURAL SCIENCE, USEFUL AND FINE ARTS. JANUARY–MARCH, 1887.*

I. ASTRONOMY.

II. BOTANY AND ZOOLOGY.

DARWIN, C.—Movements and Habits of Climbing Plants. 12mo. N. Y. 1884.

LAWSON, T.—Synopsis of the Vegetable Products of Scotland. Sq. 8vo. Edinburgh. 1852.

WOOD, A.—First Lessons in Botany. 16mo. Claremont. 1856.

ROMANES, G. J.—Jelly-fish, Star-fish and Sea Urchins. 12mo. London. 1885.

PARKER, W. K.—Mammalian Descent. 8vo. London. 1885.

BAINES, H.—Flora of Yorkshire. 8vo. 1840.

CATALOGUE of Canadian Plants. 8vo. Montreal. 1883.

BENTLEY, R.—Physiological Botany. 12mo. N. Y. 1886.

YOUMANS, E. A.—Descriptive Botany. 12mo. N. Y. 1885.

CHECK List of North American Plants. 8vo. Oquawka, Ill.

MARCHAND, L.—Botanique Cryptogamique. 8vo. Paris. 1883.

BALDWIN, H.—Orchids of New England. 8vo. N. Y. 1884.

III. CHEMISTRY.

ALLEN, A. H.—Commercial Organic Analysis. 2 vols. 8vo. London. 2d ed. 1885–86.

ROSCOE AND SCHORLEMMER.—Organic Chemistry. Vol. 3. Part 3. 8vo. N. Y. 1887.

SCHULTZ, G.—Chemie des Steinkohlentheers. 8vo. Brunschweig. 1886.

PINNER, A.—Organic Chemistry. 12mo. N. Y. 1884.

WINKLER, C.—Technical Gas Analysis. 8vo. London. 1885.

REMSEN, IRA.—Compounds of Carbon. 12mo. Boston. 1885.

IV. ENGINEERING.

HALL, W. H.—Irrigation Development. 8vo. Sacramento. 1886.

BAYLES, J. C.—House Drainage and Water Service. 8vo. N. Y. 1884.

U. S. CENSUS, Report on Mining Industries. 4to. Washington. 1886.

LORD.—Comstock Mining and Miners, U. S. Geological Survey. 1883.

U. S. COAST SURVEY, Report of Superintendent. 4to. Washington. 1886.

---

* Reader's tickets can be obtained without difficulty by any one wishing to refer to books in the library.

BESANT, W. H.—Treatise on Hydromechanics. 12mo. Cambridge. 1883.
" Steam Heating Problems. 8vo. N. Y. 1886.
" Tracts on Applied Mechanics. 4to. London. 1831.
REED, H. A.—Topographical Drawing. F. N. Y. 1886.
" Track. 4to. N. Y. 1886.
CROFTON, M. W.—Elements of Applied Mechanics. 4to. London. 1887.
RESTREPO, V.—Gold and Silver Mines of Columbia. 8vo. N. Y. 1886
DANVERS, F. C.—Coal Screening, etc. 8vo. London. 1872.
PENN. Coal Mines Inspector's Report, 1885. 8vo. Harrisburg.

V. GEOLOGY.

WALCOTT.—Palæontology of the Eureka District. U. S. Geological Survey. 1884.
U. S. GEOLOGICAL SURVEY, Mineral Resources of the United States. 1885.
WILLIAMS.—Mineral Resources of the United States, 1883–84. U. S. Geological Survey.
PRITCHARD, A.—History of Infusoria. 8vo. London. 1861.
IRVING.—The Copper-bearing Rocks of Lake Superior. U. S. Geological Survey. 1883.
FONTAINE.—Older Mesozoic Flora of Virginia. U. S. Geological Survey. 1883.
RUSSELL.—Geological History of Lake Lahontan. U. S. Geological Survey. 1885.
DUTTON.—Tertiary History of the Grand Canon District, with Atlas. U. S. Geological Survey. 1882.
PILAR, G.—Flora Fossilis. Zagrabiæ. 1883.
BROWN, T.—Fossil Conchology of Great Britain and Ireland. F. London. 1849.
CURTIS.—Silver-Lead Deposits of Eureka. U. S. Geological Survey. 1884.
CANADA Geological Survey, Report for 1885. 8vo. Montreal. 1886.
POWELL.—U. S. Geological Survey; Annual Reports 1882–83, 1883–84.
PENNSYLVANIA Second Geological Survey.
A. C. Coal Mining and Atlas.
C. 4, Chester County.
T. 2, Bedford and Fulton.
X., Geological Atlas of Counties.
Z., Terminal Moraine.
Annual Reports and Atlas 1885.

VI. MATHEMATICS.

DOSTOR, G.—Determinants. 8vo. Philadelphia. 1883.
DICKMANN, J.—Determinanten. 8vo. Essen. 1876.
PEIRCE, B. O.—Theory of the Newtonian Potential Function. 8vo. Boston. 1886.
OSBORNE, G. A.—Differential Equations. 12mo. Boston. 1886.
CARR, G. S.—Synopsis in Pure Mathematics. 8vo. London. 1885.

HARDY, A. S.—Elements of Quaternions. 8vo. Boston. 1881.
CRAIG, J.—Treatise on Projections. 4to. Washington. 1882.
HOUEL, J.—Cours de Calcul Infinetesimal. 2 vols. 8vo. Philadelphia. 1878–79.
REYE, T.—Gêometrie der Lage. 8vo. Leipzig. 1886.
GALBRAITH, J. A.—Manual of Algebra. 12mo. London.
TODHUNTER, J.—Mechanics for Beginners. 16mo. London. 1862.
HOLZMÜLLER, G.—Isogonalen verwandtschaften. 8vo. Leipzig. 1882.

VII. METALLURGY.

RICHARDS, J. W.—Aluminium. 8vo. Philadelphia. 1887.
SCHRENK, A. G.—Reise durch die Tundren der Sermojeden. 8vo. Dorpat. 1848.
STEINER, J.—Gessammelte werke. 2 vols. 8vo. Berlin. 1882.

VIII. MINERALOGY.

MOHS, F.—Grundriss d. Mineralogie. 2 vols. 12mo. Dresden. 1822–24.

IX. PHYSICS AND METEOROLOGY.

CROLL, J.—Climate and Cosmology. 12mo. N. Y. 1886.

X. MISCELLANEOUS.

MILNE, J.—Earthquakes. 12mo. N. Y. 1886.
PETTENKOFER AND ZIEMSSEN.—Handbuch d. Hygiene. 8vo. Leipzig. 1887.
CANDOLLE, A. DE.—La Phytographie. Paris. 8vo. 1880.
KLEIN.—Elements of Histology. 16mo. Philadelphia. 1886.
FLUGGE, C.—Mikroorganismen. 8vo. Leipzig. 1886.
PONCELET, J. V.—Traité des Propriétés Projectives. 2 vols. 4to. Philadelphia. 1865–66.
U. S. TREASURY DEPARTMENT; Report of the Direction of the Mint. 8vo. 1886.
HUPPE, F.—Methods of Bacteriological Investigation. 8vo. N. Y. 1886.
MARSH, S.—Microscopical Section Cutting. 12mo. London. 1882.
LOCKYER, J. N.—Chemistry of the Sun. 8vo. London. 1887.
DAVIS, G. E.—Practical Microscopy. 8vo. London. 1882.
FOSTER AND BALFOUR.—Elements of Embryology. 12mo. London. 1883.
PEYER, A.—Atlas of Clinical Microscopy. 8vo. N. Y. 1885.
STERNBERG, G. M.—Photo-Micrographs.—8vo. Boston. 1884.
CREW, B. J.—Practical Treatise on Petroleum. 8vo. Philadelphia. 1887.
HORTON, R.—Table for Measuring Hewn Timber. 12mo. London. 1863.
TRYON, G. W.—Manual of Conchology. 8vo. Philadelphia. 1886.
WALKER, W. M.—Notes on Screw Propulsion. 8vo. N. Y. 1861.
OLMSTEAD, F. L.—Walks and Talks of the American Farmer in England. 12mo. Columbus. 1859.
TRUTAT, M.—La Photographie Appliquée, a l'histoire Naturelle.

INDEX OF CURRENT LITERATURE RELATING TO NORTH AMERICAN GEOLOGY.

BY F. J. H. MERRILL.

CALIFORNIA, Northern, Notes on the Geology of. J. S. Diller. *Bull. Phil. Soc.* Washington, vol. ix., p. 4.

CANADA, Geological and Natural History Survey of. Annual Report, vol. i. Ottawa. 1885.

CANADA, Formations of the Belly River of. E. D. Cope. *Am. Nat.*, vol. xxi., p. 171.

COLUMBIA RIVER, Submerged Trees of the. C. E. Dutton. *Science*, vol., ix., p. 82. S. F. Emmons. *Science*, vol. ix., p. 156.

EARTH'S CRUST, Notes upon Warping of the, in its Relations to the Origin of the Basins of the Great Lakes. J. W. Spencer. *Am. Nat.*, vol. xxi., p. 168.

EARTHQUAKE, The Charleston. T. C. Mendenhall; W. J. McGee; C. G. Rockwood; E. Hayden; H. M. Paul. *Bull. Phil. Soc.*, Washington, vol. ix., pp. 37–44.

EARTHQUAKE, The Indiana. *Science*, vol. ix., p. 203.

EARTHQUAKES, Professor Newberry on. E. Hayden. *Science*, vol. ix., p. 18. J. S. Newberry. *Science*, vol. ix., p. 91.

FULGURITES or Lightning Holes. George P. Merrill. *Pop. Sci. Monthly*, vol. xxx., p. 529.

GREAT BASIN, Notes on the Faults of the, and of the Eastern Base of the Sierra Nevada. I. C. Russell. *Bull. Phil. Soc.*, Washington, vol. ix., p. 5.

LAHONTAN LAKE, Geological History of, A Quaternary Lake of Northwestern Nevada. J. C. Russell. Monograph xi., *U. S. Geol. Survey*.

LURAY CAVE, On the Helictites of. A. Heilprin. *Proceed. Acad. Nat. Sci. Phil.*, 1886, Part 3, p. 351.

NEW JERSEY Cretaceous. R. P. Whitfield. *Am. Nat.*, vol. xxi., p. 66.

NEW JERSEY, Southern, Miocene Fossils from. A. Heilprin. *Proc. Acad. Nat. Sci.*, Philadelphia, 1886, Part 3, p. 351.

SWAMPS, Fluviatile of New England. N. S. Shaler, *Am. Journ. Sci.*, III., xxxiii., p. 210.

TEXAS, The Cross Timbers of. Robert P. Hill. *Am. Nat.* vol. xxi., p. 172.

NOTES AND ABSTRACTS.

A Convenient Device in Levelling.

In the QUARTERLY, vol. vii., No. 2, is an article on "Improvised Surveying Instruments," in which is described a cheap but effective water-level, constructed with glass and rubber tubes, supported by a level bar made of a ¾-inch strip of board some 3 feet long. This bar is pivoted by means of a carriage bolt upon an equilateral triangle of plank, which forms the top of the tripod.

An engineer described recently a modification of this water-level and tripod, which he used in running a line of levels down an exceedingly steep bank, where it was next to impossible to set up the tripod without adjustable legs.

His method was to replace the carriage bolt in the level bar by a small tin box, such as the small boy prizes for "bait boxes," nailing the bottom of it to the under side of the level bar. He then simply set a crowbar vertically in the bank and set the tin box down on it, thus obtaining an easy, very rapid, and perfectly satisfactory set-up. By the use of the water-level, as thus constructed and mounted, his levels checked remarkably well with a longer line run less directly down the hill. **

The following letter has been received by one of the Professors in the School of Mines, and is given in all its original elegance:

SLOAN PO DUPLIN CO N. C. MAR THE 11 & 87

MR —— ——

Dear sir i will rite to you to no if you have any thing that will work to mines and Treaures if you will tell me how to get it out of the ground i will give you Ten Dollars out of the first i get and send it to you. But if you cant tell me how Please hand this to some man that can yours Truly —— —— By return mail

Resistance of Railway Trains, by —— Desdouits (From Abstracts of Foreign Transactions, by Inst. of C. E's.)

Experiments were made by the author with what he calls the elementary train—engine, tender, and brake-van—first at very low speeds, so as to get the resistance to rolling merely; and afterwards at high speeds, to determine the law of atmospheric resistance. The specifications of three of the engines used are in brief:

A. High speed: cylinders, 17.3 inches × 25.6 inches; 4 drivers, 6 feet 7½ inches in diameter. Weight: engine 36 tons, tender 16 tons. Total, 52 tons.

B. Mixed speed: cylinders, 16.5 × 23.6 inches; 6 drivers, 4 feet 11½ inches in diameter. Weight: engine 32 tons, tender 16 tons. Total, 48 tons.

C. Freight speed: cylinders, 17.7 × 25.6 inches; 6 drivers, 4 feet 4 inches in diameter. Weight: engine 36 tons, tender 16 tons; total 52 tons.

These engines were provided with the Stephenson link and ordinary slide valves. The experiments were made on a good piece of line, and sufficiently long runs made first, to get all the parts warmed up and well lubricated. A dynamometer of special construction, with pendulum movement, was fixed on the platform of the tender. The throttle was gently opened, so as to give a speed of about six miles per hour, and then suddenly closed and the engine allowed to come to rest. The following results were obtained, being the resistance in pounds per ton of gross weight of engine and tender:

A. Passenger engine, 6.94.

B. Mixed service, 8.06.

C. Freight service, 10.53.

Experiments on engines precisely similar, but fitted with cylindrical valves, gave results about 16 per cent. less, or in favor of the latter.

Similar experiments were made with the connecting-rods and valve-gear dismounted, in order to find the resistance of the mechanism. The engine under test was brought up to the desired speed of about 5 miles per hour by an auxiliary engine. The results, in pounds per ton of weight of engine and tender, were as given below, the first figures being for the engine entirely mounted, the second with connecting-rods and valve-gear dismounted, and the third with the coupling rods dismounted in addition.

A. Passenger, ...	7.17	——	5.26
B. Mixed, ...	8.06	5.04	4.93
C. Freight, ...	8.96	6.94	6.94

So that the mechanism absorbs from 22 to 27 per cent. of the whole resistance of the engine.

The tenders separated from the engines gave about 5.60 to 6.27 pounds per ton, resistance.

Trials with trains of 7 or 8 cars, with wheels 41 inches in diameter, and loaded to 4 and 5 tons per axle, gave resistances respectively of 3.47 and 3.58 pounds per ton.

The general conclusion for all sorts of cars was that the resistances vary from 3.36 to 4.03 pounds per ton, and that anything in excess of 4.5 pounds was due to defective lubrication. Atmospheric resistance, of course, was *nil* in the above results.

Experiments were made on the resistance of the air at high speeds, by suspending flat boards, movable on axles and counterweighted, laterally from a train. The train was run at increasing velocities, and the instant was noted when the resistance of the air caused the lifting of the weights and reversal of the boards.

It was deduced from experiments that the resistance on a surface 3.94 inches square, in calm weather, at a speed of 44.5 miles per hour, amounted to 1.14 pounds, or to 106 pounds per square foot; and for other velocities the resistance varies as the square of the speed.

It was also found that this resistance to pressure could be reduced one-half by fitting angular prows on smoke-box, buffer-beam, foot-plate, and other parts.

BOOK REVIEWS.

SIXTH ANNUAL REPORT OF STATE MINERALOGIST OF CALIFORNIA. Parts I. and II. 145 and 222 pp. 8vo.

The report contains alphabetical lists of the occurring minerals, building stones and building materials, with localities; descriptions of the various mineral springs, tables of altitudes, legal distances and routes of travel from San Francisco, the United States mining laws and special articles on "Mine Drainage," "Concentration of Gold and Silver Ores on the Pacific Coast" and "Chlorination."

Part I. by Henry G. Hanks; Part II. by William Irelan, Jr. *

ELEMENTARY TREATISE ON DETERMINANTS. By William G. Peck, Ph.D., LL.D. A. S. Barnes & Co., 1887.

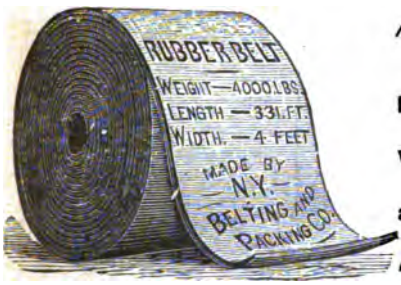
An elementary knowledge of Determinants is a necessity for any study in the more comprehensive mathematical textbooks of the day. Any recent work on analytical geometry or calculus reveals this at a glance. The simplicity of the subject and the field of its utility are not generally understood by those who have not given it attention. Indeed, false notions of its abstruseness predispose the minds of many young students against it. A book that in short space might remove mistaken ideas of its difficulty and substitute for them an appreciation of its simplicity and utility has long been a desideratum. The writer believes that the little book on Determinants from the pen of Professor W. G. Peck satisfies the want. The special purpose in the preparation of this book was to provide for the wants of a class about to begin the study of modern analytical geometry. It so well served its purpose that its publication was deemed desirable. In fifty pages the subject is presented to an extent sufficient for ordinary mathematical reading. The book will also serve as an excellent introduction to a deeper study of the subject, an opportunity for which is offered by an exceptionally fine collection of works in Columbia College library. This includes the treatises of Brioschi, Baltzer, Guenther, Salmon, Dostor, Muir, Scott, Matzka, Diekmann, Hanus; also chapters in Peirce's *Analytical Mechanics*, Houel's *Calculus* and Burnside and Panton's *Theory of Equations*. A full set of Crelle's *Journal* supplies, in addition, many valuable articles, and but for the absence of the greater part of the *Quarterly Journal of Mathematics*, a magazine especially rich in this, we should be entirely satisfied. It is worthy of note in the same line that the *Quarterly Journal* for June, 1886, contains an article by Muir supplementary to a previous article by himself, October, 1881, giving in connection with that a complete bibliography of the subject. . . .

Since the above review was written an order has been issued from the office of the Secretary of War requiring the use of Professor Peck's book in the course at West Point. J. K. R.

RUBBER BELTING, PACKING, HOSE,

RUBBER TUBING, RUBBER MATS,

MATTING, and STAIR TREADS.



All kinds of Rubber Goods for Mechanical Purposes.

DIAPHRAGMS, GASKETS and RINGS, ROLLS, STOPPLES, VALVES and TUBING—BLACK or WHITE, for GAS, WATER, and INSULATING RUBBER BAGS.

Largest Manufacturers in the U. S.

New York Belting and Packing Co.,

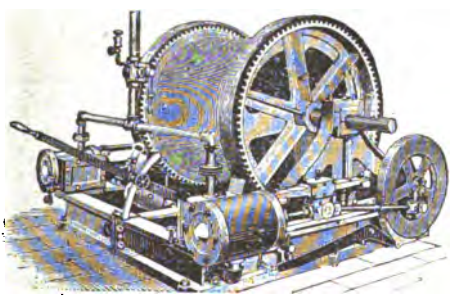
15 PARK ROW (Opposite Post Office), **NEW YORK.**

JOHN H. CHEEVER, TREASURER.

Improved Hoisting Engines

WITH

Wire-Rope Drums and Safety Brakes.



Specially adapted to Mining Interests.

ALSO COMBINED

Engines and Boilers, and Horizontal Stationary Engines.

LIDGERWOOD MFG. CO., 96 Liberty St., N. Y.

NEW CATALOGUES NOW READY.

WOODBRIDGE SCHOOL

(Late School of Mines Preparatory School)

No. 32 East Forty-Fifth Street,

NEW YORK.

Distinct Scientific and Classical Courses, introductory to all colleges; also Junior Department. The Scientific Course is carefully planned to be preparatory to the Columbia School of Mines.

INSTRUCTORS

PRINCIPAL:

J. WOODBRIDGE DAVIS, C. E., Ph.D.,
Mathematics, English.

ASSISTANTS:

PHILIPP J. J. VALENTINI, Ph.D.,
German Language.

APPLETON P. LYON, A.M.,
English and Classical Languages.

JOHN K. GORE, A.M.,
Mathematics, History.

FERDINAND G. WIECHMANN, Ph.D.,
Chemistry, Physics.

A. L. SEVESTRE,
French Language.

H. L. FAIRCHILD, B.S.,
Comparative Physiology, Geology.

HOBART B. JACOBS,
Drawing.

WILLARD H. POOLE, A.B.,
Latin, English Grammar.

Registered at the New York Post Office as Second Class Matter.

VOL. VIII. No. 4.

THE

SCHOOL OF MINES QUARTERLY.

JULY, 1887.

CONTENTS:

Drift-Mining. By T. Egleston, Ph.D..... 289
Color-Contrast. By Prof. O. N. Rood..... 307
Concentrated Rolling Loads. By R. W. Hildreth, E. M..... 317
Geological Notes. By Prof. J. S. Newberry..... 327
The Separation of Nickel and Cobalt from Iron. By J. B. Mackintosh.. 335
Concentration of Gold and Silver Ores on the Pacific Coast. By J. M. Adams, E. M..... 336
Scheme for Qualitative Blowpipe Analysis. By A. J .Moses..... 359
The Comparative Delicacy of some Qualitative Tests. By J. S. C. Wells 366
Inter-Collegiate Boat Racing. By Prof. W. P. Trowbridge..... 368
Additions to the Columbia College Library in the Department of Natural Science, Useful and Fine Arts, April and May, 1887..... 373
Index of Current Literature Relating to North American Geology. By F. J. H. Merrill..... 375
Notes and Abstracts..... 376
Book Reviews..... 382

COLUMBIA COLLEGE.

NEW YORK CITY.

1887.

SCHOOL OF MINES QUARTERLY.

VOL. VIII., 1886-87.

EDITORS.—J. K. Rees, J. B. Mackintosh, A. J. Moses, J. L. Greenleaf, E. A. Congdon H. Parsons.

J. L. Greenleaf, *Managing Editor;* A. J. Moses, *Business Manager.*

ASSOCIATE EDITORS.—F. A. P. Barnard, J. S. Newberry, T. Egleston, W. P. Trowbridge, H. S. Munroe, F. R. Hutton, Elwyn Waller, P. de P. Ricketts, M. W. Iles, R. D. Irving, H. B. Cornwall, P. T. Austen, C. M. Rolker, J. A. Church, W. B. Potter S. A Reed, W. B. Devereux, J. M. Adams, H. M. Wilson, J. C. F. Randolph.

Subscription price two dollars per annum, or fifty cents per number.

NOTICE TO GRADUATES.—The Quarterly will print in the July number of each year a complete list of all graduates of the School of Mines, compiled from the records of the Secretary of the Alumni Society. It is requested that the Editors be notified of any changes by filling out the blank on next page and mailing it to

THE SCHOOL OF MINES QUARTERLY, New York City.

FIELD, ROBERT P.,

CONSULTING,

Mining and Civil Engineer.

Coal Mining and Coking a Specialty.

148 S. Fourth Street, Philada., Pa.

Box 1228.

OLCOTT, EBEN E., E.M.,

MINING ENGINEER

AND

METALLURGIST,

10 Cedar Street, New York City

Cable address, "Kramolena."

Examines and reports on mines or metallurgical establishments.

Has had considerable experience in Gold and Silver Mines in South America and Mexico.

Eastern representative of the M. P. Boss Continuous Milling System.

LEDOUX & COMPANY,

Consulting Engineers and Metallurgists,

10 Cedar Street, New York.

Complete Sample Works and Laboratories. Assaying, Sampling, Concentrating and Milling small or large lots of ANY ORE. NEW PROCESSES and NEW MACHINES tried, and their PRACTICAL VALUE determined.

Mineral and Commercial Analyses of all kinds,

☞ Special terms and inducements offered to professional men, including School of Mines Alumni.

PISTOR, WILLIAM,

ARCHITECT,

No. 35 Broad St.,

NEW YORK.

MAYNARD, GEO. W.,

Mining and Metallurgical

ENGINEER.

Designs for Mining, Dressing, and Metallurgical Plants.

OFFICE, 35 BROADWAY, NEW YORK.

RANDOLPH, JOHN C. F.,

Consulting Mining Engineer,

85 Broadway, - - NEW YORK.

Examines and reports on mines.

Extensive experience in all parts of the world.

Cable address, "RHOSGOG," New York.

THE

SCHOOL OF MINES QUARTERLY.

VOL. VIII. JULY, 1887. No. 4.

DRIFT-MINING.

BY T. EGLESTON, PH. D.

(Concluded from page 220.)

THE ventilation of the tunnels requires considerable attention, but is rarely ever difficult. The workings in the mine are sometimes connected with the surface by a tunnel or shaft, or both, independent of the bed-rock of the tunnel. In such a case there would be a temporary tunnel in the drifting ground and a permanent one in the bed-rock. The tunnel then becomes an air-way, and is connected with all the cross drifts on one side of the ground which is being drifted, and not through the middle of it. This gangway is always well timbered, and the ground in its vicinity must not be disturbed while the mine is being worked, as any caving which would close it might result in serious accidents and loss of life. It is used not only for ventilation, but for access to the mine and for traffic. When there is not a sufficient difference of elevation of temperature between the two tunnels to cause the air to circulate a shaft is made connecting the air-gangways with the surface, and an artificial draft is made by the use of fire. When there is only one opening in the mine ventilation must be secured by fans, which are run usually by water power.

The main and cross drifts are run in the gravel on the surface of the bed-rock if it is hard and contains no gold. If the bed-rock is

soft, and does contain gold, 8 or 10 inches, sometimes 2 feet of it, are taken up. The gravel from different drifts is washed separately, in order to determine the probable value of the adjacent ground. The ground is divided into squares for the purpose of prospecting. Where there is hardly any uniformity in the distribution of the gold in the gravel this is not done to any extent. In estimating whether or not a certain amount of ground will pay, the gross yield, or the yield per carload, is not the only thing which it is necessary to take into account. The amount of timber or lagging, and the hardness of the gravel must be taken into consideration. No general rule can be given as to what gravel will pay and what will not. The degree of richness which makes mining profitable must be determined in each special case. In taking out the gravel only the finer portions are taken out and washed. All the large boulders are piled up in the empty chambers which have been worked out. As soon as a gangway has been worked in 7 or 8 feet the track is advanced to the heading, so as to bring the cars close up to the face. When this is again worked off 7 or 8 feet in depth the track is again moved and the cars brought up again. When ten or more feet of gravel is mined the breasting is done in two benches. Very long timbers are used, and if the gravel is soft and liable to cave great care must be taken to place them and the lagging properly. Except where the gravel is very hard and cemented large amounts of timber are required. In many mines, in addition to timbers and caps placed closely together, it is necessary to use top lagging, driving the latter ahead of the timbers, and close up to the face as the gravel is taken away. Blasting is only required in extremely hard and cemented gravels. In most of the mines the ground is so soft that it can be easily worked with a pick. As far as practicable the gravel is broken with the pick, as it is difficult to use powder to advantage. On the Blue Lead in Sierra County the gravel is quite soft. It is washed by projecting a stream of water under a great head of pressure upon the loosened dirt. The cars and track used in the gravel mines, when they discharge through shafts to a lower rock tunnel, are somewhat different in construction from those used for carrying the gravel to the dump.* The track in the workings has to be moved frequently, and is often made in sections so as to be done without difficulty. Sometimes wooden rails are used, but generally, if used, they are faced with strap-iron 2 inches wide by ¼, ⅜, or ½ an

inch in thickness. An inch thick, however, is found to be the best. Wooden rails, however, whether strapped or not, are being rapidly replaced by iron or steel T rails. Those generally used vary from 16 to 42 pounds to the yard. The use of iron or steel rails has a great advantage over wooden rails, because, when the ground heaves, as it very often does, the rail rises in long swells, instead of making sharp bends as with wood. In the main tunnel, and in all the drifts which are permanently used, the tracks should be laid with great care. The wear and tear of the rails is large, and frequent repairs are necessary. The gauge of the track varies from 16 to 22 inches. The size of the mine car is generally from 4½ to 5 feet long, 24 inches wide and 20 to 30 inches deep. They are generally calculated to hold about a cubic yard of loose dirt, or from 600 to 700 pounds to a ton. In making these calculations it is computed that 17 cubic feet of clay, 18 cubic feet of earth or gravel in the bank, 25 cubic feet of sand, and 27 cubic feet of broken earth or gravel when dry will weigh 1 ton. Both box and platform cars are used. The gravel is shovelled into, or on to, these cars, which in the mine are moved by hand. When a shaft is used it is loaded into buckets on wheels. The mine car, which carries the gravel from the breast to the shute, is only half the size of that which carries the gravel from the shute to the outside. These cars carry from 400 to 1000 pounds.

The cars are generally made of oak, but iron cars are sometimes used, and are much better, both in durability and economy of running, and besides they weigh less. The mine cars are dumped into a vertical shute with a gate at the bottom, which holds the gravel until an empty dump-car is ready to be filled with it. These are generally run out of the mine by animals. It is best to use horse or mule power rather than hand. Occasionally mine locomotives are used, as at the Bald Mountain mine, where a mine locomotive draws 60 cars in a trip. This cannot be done, however, unless the amount of material to be moved is very great. As a general thing, the tails, after being discharged in the rivers, are retained there by means of dams to be treated again.

The cost of the car-load of gravel at the Mabel mine, in September, 1886, at the foot of the incline, was, including every item, $1.12. The cost of hauling to the dump-house, $0.07 per load, or a total of $1.19 per load delivered at the dump-house. This cost is itemized as follows:

Timber, per car-load,	$0.02
Powder, fuses, caps and crushers,	0.09
Labor, superintendence, etc.,	0.88
Royalty and rental,	0.20
	$1.19

The yield was $1.55, leaving a net profit of $0.36 per car-load.

The method of stating the yield varies. In some places, the standard is the car-load, which is calculated at 16 to 20 cubic feet for one ton; but, as the size of the car depends upon the size of the tunnel, the car-load, without giving the dimensions, cannot be any standard of value. It is supposed that 27 cubic feet in the car represents 20 cubic feet of material in place. The expansion of the gravel, after it has been broken, is a matter of considerable consequence. Nine cubic feet of ground in place, when broken, will fill a box of 12 cubic feet capacity. An estimate, based upon cubing the feet without explanation, would, therefore, be entirely erroneous. This distinction between ground in the mine and ground broken should therefore always be maintained. In the mine it is so compact as often to require to be blasted. Experience at Bald Mountain has shown that one cubic yard of gravel in place will fill two cars. Another way of estimating the yield is per foot of channel. In some places the value is expressed as so much per acre or as so much per superficial yard of channel-ground, but the height of the ground is not uniform. In some places it is 3, and in others 4 or 5 feet. Taking the acre as a standard it is estimated that the yield throughout the state has been from $20,000 to $80,000 per acre, or not less than from $200 to $300 per linear foot; the value of the gravel worked in the Forest Hill district previous to 1860 yielded nearly $250,000 per acre. The only way to definitely express the value, is to express it by the cubic yard, but this method of expression is not in general use, so that it is not easy to get a standard of value for comparison between different mines.

The yield has formed the subject of many investigations during the last few years, as the opinion prevails that the future product of the gold in California for the next 20 years will depend largely upon this source of supply. The gold yield of these places is very various. Single car-loads of gravel have been taken out that paid $11,000. $800,000 was once taken from half an acre of ground; but generally the gravel is not so rich. Mines that have run upon old river bars, such as were always found in the ancient river channels, are very common; as in every other enterprise, only average ground

can be counted on. Mr. E. S. Thurston, for several years a mining superintendent in Sierra County, has compiled the product and rate per foot of channel of the leading mines between 1870 and 1880.

Name.	Length of Location.	Yield per Cubic Foot.	Total Yield.
Union, . . .	2400	$625.	$1,500,000
Hawkeye, . . .	800	437.50	350,000
Pittsburgh, . . .	860	506.	420,000
Monumental, . .	1040	312.	325,000
Empire, . . .	1560	482.05	752,000

In order to make it pay, the gravel should contain, under ordinary circumstances, from fifty cents to one dollar per car-load of 16 cubic feet. The minimum value of ground to be worked should thus be from fifty cents to one dollar per cubic yard of gravel extracted.

The gold is extracted either by sluicing or milling. The sluicing is in every way similar to that employed in hydraulic mining. The milling process is adopted where the gravel is so cemented together that it cannot be sluiced. It is then crushed in an ordinary stamp mill. The way the gravel is to be treated to extract the gold depends upon its texture. When the material is compact but not cemented, it is readily washed. The gravel is dumped into a bin, which has a rifled sluice at the bottom. A stream of water is turned on to this, and the gravel is run through several hundred feet of riffled sluices charged with quicksilver. The pipe which is used is generally a two-inch nozzle, and the water is projected under a head of 50 to 100 feet. The sluices are usually from 18 to 20 inches deep, and are set on a grade of 4 to 6 inches to the rod, sometimes a little less. The material which has passed the sluice is generally deposited in a side cañon, and is often washed over again at some future time, in another set of sluices. These tails swell and break up further after exposure and are sometimes washed even a third time. The tails are generally washed over after the channel is worked out. They are expected to contain about 1 per cent. of the amount obtained at the first washing, but they often contain more. Their richness depends on the amount of gravel washed at any one time, and on the care exercised in doing it. The method, however, as compared with hydraulic mining is expensive. The mine usually produces water enough for the treatment.

The gravel extracted is piled in some convenient position. As the gold on the bed-rock is oftener coarse than fine, it is frequently sluiced without quicksilver, but mercury is generally used. As the grade of the sluice can be controlled at will, it need not be very

long. At the Mabel mine, the gold on the bottom of the channel is coarse, but grows fine as the rims are reached. The finer the gold the more difficult it is to save it. The bars made at this mine from it are .8986 fine.

The dump for the gravel outside of the mine and the arrangements for washing vary according to the different positions. If the tunnel enters the mine from the head of some steep ravine, the tank for the mine waters will be directly in front of it. This tank is generally large enough to hold all the mine water for the twenty-four hours. Below it and running down the bed of the ravine sluice-boxes are fixed. The track which leaves the tunnel divides in all the large mines into two or three branches. The main one crosses the water tank and is continued on a trestle over the sluices to the dump. The dump is made by covering the sloping sides of the ravine with planks and sheet-iron, so that the gravel slides into the sluices during the washing. A second branch runs along one side of the ravine and is used for taking to a special dump the gravel from the drifts and ground it is desired to prospect, so that they can be washed separately. The third branch runs along the other side of the ravine to such a distance as to be clear of the sluices, and is used for cars containing waste rocks from the main tunnel. This is dumped where it will be out of the way. At some mines only two tracks are run—one, one side of the ravine or in the middle, and the other on the other side. In small mines only one track is used for all these purposes. These tracks and the entrances to the tunnels are generally roofed over as a protection from snow and rain. Adjoining the main dump house there is a prospecting dump where gravel is washed in small lots to determine whether it is rich enough to work. The washing is done once a day, or more frequently if the quantity of gravel is large. The sluices are cleaned up at once as a precaution against robbery. The gold is, as a rule, coarse and heavy, and requires no quicksilver. Some is occasionally placed in the lower sluices to collect the fine gold.

The gravel from some of the Blue Lead channel mines is very compact, and consequently it has to be crushed in a stamp mill before the gold can be obtained, which makes it expensive to mine and very costly to get the gold out. The amount of water used is not so large as in hydraulic mining, since the quantity of material to be treated is much smaller, but it is relatively about the same. The ordinary duty of a 24-hour miner's inch, equivalent to

2234 cubic feet, varies from 3 to 20 cubic yards, depending upon the character of the gravel which is treated. When gravel is cemented, and sometimes when it is loose but not loose enough to be treated in the sluice, it must be crushed in stamp mills of the same kind as those used for quartz-milling, but fitted with coarser screens. The method of treatment is always battery amalgamation with riffled sluices. The gravel from the Lyon mine, El Dorado County, California, is crushed by a 20-stamp mill driven by water power. The stamps weigh 850 pounds each, and drop 80 times per minute, with a 10-inch fall. Thirty miner's inches of water, under a head of 130 feet, furnish the motive power. Of the total amount of gold saved, 80 per cent. is caught in the battery. Outside of the mortar, the pulp flows over a silver-plated copper apron, and thence through 800 feet of sluices. But little gold is recovered from the sluices, however. The material is crushed without previous sizing.

The mill of the Paragon Company, in Placer County, California, has 10 stamps, of 850 pounds each, with steel shoes and dies, dropping 90 times per minute, with a fall of 10 inches. The capacity of the stamps is 40 tons per 24 hours. The screens are sheet-iron, with $\frac{8}{16}$ inch round holes. The coarser gravel and boulders are not crushed, but only the finer and softer gravel. The greater part of the yield of this mine comes from the stamps. From 60 to 70 per cent. of all the gold saved is caught by amalgamation in the battery, from 20 to 25 per cent. on aprons, and the remainder by a concentrator and in 150 feet of sluices. The record of a continuous run from September 19th, 1879, to April 14th, 1880, gave the following results:*

Car-loads of gravel crushed,	4,241
Total yield,	$44,835 53
Average yield per car-load,	$10 57
Average yield per ton,	$7 05
Average cost per car-load, mining and milling, including dead work,	$3 94

A car-load at this mine contains, on an average, 28 cubic feet, and weighs about one and a half tons. The yield per ton was, therefore, $7.05. The gravel is dumped from the track of the tunnel to the mill platform, where large rocks are picked out, and carried to the dump heap, which is occasionally sluiced and yields some gold. All the other material is fed by hand to the mortars, which have a single discharge through screens with round holes,

* Production of Gold and Silver in the United States, 1880, p. 322.

$\frac{3}{16}$ of an inch in diameter. The pulp flows over a table 8 feet long, provided with grooves or riffles charged with quicksilver. It then passes through rubbers to the concentrator where a small portion of the gold is saved. The mill is run by steam power, and consumes three cords of wood per twenty-four hours. The tunnel in the year 1880, was 1900 feet long. The force of men employed consists of two engineers at $7.50, two feeders at $7, three helpers at $6, one foreman at $4, one blacksmith at $3.50, thirty-one miners and carmen, $93; total, $121.

At the Centennial Mine the gravel is hoisted through an inclined slope 200 feet in length and dumped into a bin, from which it passes through an automatic feeder into a revolving cylinder of boiler iron, provided in its interior with railroad rails. The cylinder is 20 feet long and 3 feet in diameter. It works like a Brückner Furnace. The gravel is thrown in and in the length of the cylinder is supposed to fall about 13 times. The result is that it is broken and cleaned. No stamp mill is used. At the lower end of the cylinder there is a set of bars which are about 3 feet long and 1¼ inches apart, which allows the fine portion to pass through. This falls into the feed-box of the stamp-mill, while the large stones fall into a car to be thrown away. Cement to pay for crushing must necessarily be much richer than gravel. The expense for milling is less for cement than for quartz, as a coarse mesh screen can be used which delivers much more rapidly; besides, the cement is considerably softer.

The sluice is cleaned in sections twice a month, and much oftener if the ground is very rich. A general clean-up is made twice a year, when the worn blocks in the sluice are turned over and those no longer fit to be used are replaced. With turning the blocks last ten months.

Yield of the Paragon Claim, Placer County, California, for Six Seasons, 1874 to 1879.

Total production for the period, ...	$243,075 87
Dividends paid, ...	119,670 14
Average yield per miner's inch, calculated on a basis of 24 hours' inch under 6-inch pressure, . .	2.54

The monthly yield of the Mountain Gate Mine has been from $10,000 to $12,000, nearly all of which was taken from the old quartz channel. The total yield of the mine up to 1881 was $1,500,000. The ground worked on the Forest Hill Divide

yielded at the rate of a million dollars per mile of channel. The highest yield for any one year was for 1866, when the product was $440,000 from this group of mines. The yield somtimes ran to $10 per car-load, and equalled from $300 to $500 per linear foot.

The North American, near the head of Slate Creek, has an altitude of 5630 feet above the sea. The tunnel through which it is worked is 4400 feet in length. About 150 cubic yards of gravel are carried out of the mine daily by mules and are washed with 50 inches of water. There are 50 miners, 20 of whom are white men and the rest Chinamen.

At the Bald Mountain Drift Claim, Sierra County, the channel is over a mile in length. The gravel is drawn out by a locomotive, drawing as an ordinary train, from 16 to 20 cars, carrying about two-thirds of a cubic yard each. During the year 1884 they were treating about 150 cars a day. This amounts to 100 cubic yards a day or about 30,000 cubic yards a year. They employ 75 white men. The Bald Mountain Extension at Forest City treats about 34,000 cubic feet of gravel and employs 75 white men. The Ruby, near Forest City, treats 15,000 and employs 40 men. The Derbec, near North Bloomfield, has a vertical shaft 400 feet in depth and a tunnel connecting with it; it treats 21,000 cubic yards, employs 72 men and uses about 100 inches of water.

The cost of opening a large drift mine and getting it ready for work is necessarily very large and requires beside a great deal of time. The length of the main channel is very often from 2000 to 3000 feet. It is usually run in hard bed-rock and must be finished before the pay gravel can be reached. On its proper location depends the whole success of the enterprise. A hundred feet in length saved represents a very large saving in cost.

The ordinary conditions which determine the expenses of drift mining vary very greatly. Some deposits which are favorably situated, in which both the gravel and water run out of the main tunnel, can be worked at a very low cost. If, however, the water is difficult to manage, the ground very loose or quicksands occur, and the pay gravel is irregularly scattered over the bed-rock, the expenses may be very large. In some cases, gravel yielding not over a dollar per cubic yard can be worked with a profit. In other localities $3, $4, $5 and $6 a yard will hardly pay expenses. At the Lion Mine, El Dorado County, California, where stamps are used for crushing the cement, work can be done on cement yielding $3 a yard. At the Paragon Mine in Placer County, where there is also

*Tunnel Claims near Dogtown, Calaveras County, California.**

	Hammerschmidt, Hensel & Co.	Barney, Hurle & Co.	Bully Company,	Buckeye Company.	Deitrich & Co.
Inches of water used in sluice washing	25 to 30.	30.	30.	30.	30.
Inches of water used in hydraulic washing	20.				
Height or fall	100 feet.				
Supply of water lasting in the year	6 to 7 months.	6 to 8 months.	6 to 8 months.	6 to 8 months.	6 to 8 months.
Cost of water (sluicing) per day	$4.	$4.	$4.	$4.	$4.
Cost of water (hydraulic) per week	$20.				
Air-shafts	One of 70 feet; one of 148 feet.	One of 105 feet.	4.	4.	10.
Length of tunnel at present	1500 feet.	One of 200, one of 400, and one of 300 feet.	700 feet.	1000 feet.	1200 feet.
Height of drift (all pay-dirt)	6 feet.	4½ to 5½ feet	4 feet.		
When this claim commenced	In 1865.	In 1862.	1870.	1870.	1870.
Area of ground drifted out and worked	9166 superficial square yards.	5600 superficial square yards.			
Number of cubic yards drifted out	18,332.	7500 square yards.	3000,		
Length of ground unworked	400 feet.	600 feet.	1000 feet.		
Average of cement-gravel extracted per day	20 to 25 car loads; about 25 square yards.	15 to 20 square yards.	Over one-half.		
Quantity of refuse left in the stope	Over one-half.	Over one-half.	2000 sq. yds.		
Quantity of gravel-cement washed during last year and extracted	2200 square yards.	Not washed.	$700.		
Yield of cement-gravel washed	$4 to $5 per square yard.	$4.	$700.		
Total yield last year	Over $8000.	Not washed out.			
Total yield since commencement of this claim	$70,000.	$30,000.			
Gold, description	Small flat particles.	Both coarse and fine.			
Wages paid to underground-drifters	$2.50.	$2.50.	$2.50.		
Number of men hired	4.				
Number of men working	8.	4.	4.	4.	4.
Composition of deposit	Red soil, small and large white and blue quartz, boulders, pieces of dark blue slate, quartz, and mica slate, cemented granite gravel.	Red soil, quartz, gravel, slate, granite, sand—all cemented.	Gravel, cemented.	Gravel, cemented.	Gravel, cemented.
Bed-rock	Dark blue slate, full of cubical pyrites.	Dark blue slate, veins of quartz.	Blue slate.	Blue slate.	Blue slate.
Direction of tunnel and course of deposit-channel.	E.N.E.	E.	S.E.	S.E.	S.E.

* Mining Commissioners Report, 1872, p. 72.

a crushing mill, $3 yields a good profit over all expenses. At the Hidden Treasure Mine, Michigan Bluffs, it costs about $2 per ton. The accompanying tables, give a fair idea of the details of the cost of drift-mining enterprises in the United States.

The Bald Mountain Mine of Sierra County, California, which has been worked in a systematic manner since 1872, may be considered as a representative mine of the drifting class. The company owns 7,500 linear feet of the channel, of which about 4000 feet had been worked up to the close of 1880. Up to August 1st, 1880, there had been worked 3,850 feet of channel, yielding $1,788,000, or at the rate of $464 per linear foot, at an expense of $240 per foot. The yield was on an average of $2.17 per car-load, or $1.75 per ton.

The original outlay on shaft and tunnel was,	$20,000
Purchase of tailings, outlet and disputed title,	31,000
Working expenses to August, 1880,	923,000
Total outlay,	$974,000

The work of this company is given in the table below.*

Year commences July 1.	Car Loads.	Gross Yields.	Per Car Load.	Dividends.
1872 to 1875.....	195,940	$544,000 00	$2 77	$284,000 00
1875 to 1876.....	100,080	296,341 76	2 96	150,000 00
1876 to 1877.....	98,044	235,803 57	2 40	70,000 00
1877 to 1878.....	106,160	269,755 00	2 54	120,000 00
1878 to 1879.....	90,274	164,909 00	1 82	40,000 00
1879 to 1880.....	86,378	188,897 40	2 18	60,000 00
1879 (Oregon Creek).	.....	3,000 00	.....	.....
	676,876	$1,702,701 73	†$2 17	724.000 00
July 1, 1880.....	.....	16,914 38	.....	20,000 00
To Aug. 1, 1880.....	.....	$1,728,616 11	.....	$744,000 00

The total outlay of the Ruby Mining Company from January, 1880, to April, 1883, was‡

Main tunnel, construction,	$62,874 36
Building the roads, flumes, etc.,	11,751.23
General expenses,	9,404.57
Prospecting work,	8,203.14

Up to April 22, 1883, there were 2400 feet of main tunnel driven through solid rock, 11,217 feet of drifts in the channel, and

* Production of Gold and Silver in the United States, 1880, p. 324.

† General average.

‡ Production of Gold and Silver in the United States, 1883, p. 718.

150 feet of raises and winzes. Nearly the whole of this work had to be done before the mine commenced to yield a profit.

The expenses of this mine from April 16 to April 22, 1883,* were:

Labor, 50 men at $3,		$150
Outside men and management,		25
Powder, fuse, caps, steel, iron, light, timber and incidentals,		29
Or, per day,	$204	
A week of six days,	$1,224	
Running expenses on Sunday,	30	
Running expenses for seven days,	$1,254	

The result was:

Car-loads of pay dirt,	709	
Car-loads of waste dirt,	200	
Total car loads,	909	
The cost per car load was,	$1 34	
The yield was 161 ounces in the head boxes cleaned-up, at $17.50 an ounce, equal to,		$2,817 50
Lower boxes not cleaned up, estimated at one-seventh of the head box,		402 50
Total,		$3,220 00
The pay per car load was,		3 64
Net profit for week,		19 66

This company adjoins the Bald Mountain Company.

The following tables give the product of some of the most important mines in California.†

Mine.	Locality.	Length of Claim.	Yield per Linear Foot.	Product.
		Feet.		
Hidden Treasure.....	Placer county..	10,560	$294 00	*a* $274,283 00
Bald Mountain.....	Sierra county...	7,500	464 00	*b* 1,728,616 00
Hawkeye.....	do.	800	437 50	*c* 350,000 00
Empire	do.	1,560	482 05	*c* 752,000 00
Monumental.....	do.	1,040	312 00	*c* 325,000 00
Pittsburgh	do.	860	506 00	*c* 420,000 00
Union	do.	2,400	625 00	*c* 1,500,000 00

a To May 1, 1880. *b* 1872 to August, 1880. *c* 1870 to 1880.

* Production of Gold and Silver in the United States, 1883, p. 718.

† Report of the United States Census for 1880, vol. xiii, p. 303.

*Live Yankee Claim.**

Length of tunnel,	2,600 feet.
Yield from 1855 to 1863,	$698,534.00
Cost of opening and mining,	$370,166.00
Total product of mine,	$1,000,000.00
Total receipts to July, 1874,	$328,352.38
Total expenditures,	$164,352.38
Number of car-loads extracted,	115,950.00
Paid per car-load, one cubic yard,	$2.76
Paid per square foot of ground,	$1.09
Number of square feet washed,	292,200.00
Superficial feet contained in the channel,	7,232.00
Which, at nine cents per square foot, is equal to,	$7,882,880.00

They use 4000 to 6000 pounds of giant powder per year, 2000 to 3000 pounds of steel, and 300 to 400 boxes of candles. There are 85 miners in the mine at $3 per day; 30 cars, which are used for extracting the gravel which is dumped in the yards to be sluiced. The sluice is 6600 feet long, 17 inches in width, and 18 inches high. It has a grade of 6 inches in 12 feet and is paved with blocks 16x16 inches and 4 inches thick. The gold is so coarse, and settles so easily between the blocks, that no quicksilver is used. The head of water is 100 to 150 inches.

At Gold Run, in the year 1872, a tunnel 1600 feet long, with branches and gangways, was run for working cement. Twenty-five men at $3 per day were employed, who delivered between 40 and 50 car-loads of cement in 24 hours, the quantity depending upon the nature of the ground. They worked a breast 110 feet wide, taking 6 to 7 feet in height. The gravel was dumped directly into a stamp-mill at the mouth of the tunnel. This mill had 8 stamps of 500 pounds each, with a drop of 8 inches. It was run by a hurdy-gurdy wheel 10 feet in diameter, with a pressure of 80 feet of water. The capacity of the mill was between 35 and 90 car-loads, depending upon the rapidity with which the mine was worked.

The following table gives the operations of the Indiana Hill Blue Gravel Company from the date of incorporation, April, 1872, to the close of the mining season of 1874:†

---

* Mining Commissioners Report, 1875, p. 153.

† Mining Commissioners Report, 1875, p. 100.

Mining Season.	Number Car Loads.	Yield per Load.	Total Yield.	Total Cost Mining and Milling.	Net Profit.
1872	3,680	$5 27	$19,410 97	$7,360 00	$12,050 97
1872 to 1873	6,300	4 00	25,200 00	13,175 00	12,025 00
1873 to 1874	10,017	3 08	30,811 50	20,034 00	10,777 50
Total,	19,997	.....	$75,422 47	$40,569 00	$34,853 47

Recapitulation.

Average yield per car-load (19½ feet),	$3 77
Average yield per ton of 2000 pounds,	4 71
Average yield per cubic yard,	5 29
Average cost per car-load (19½ cubic feet),	$2 03
Average cost per ton of 2000 pounds,	2 54
Average cost per cubic yard,	2 90
Profit per car load,	$1 74
Profit per cubic yard,	2 39

It is estimated that the yield of the cement will be from $3 to $3.50 per cubic yard in cement mills. At French Coral the yield was $3.50, and the cost $1.10.

The following are the statistics of some of these mines in the Slate Creek basin channels at Holland Flat in Potosi:*

	Height of Ground.	Number of Square Feet.	Total Yield.	Yield per Square Yard.
Down East Co.....	4 ft. 6 in.	287,000	$346,000 00	$10 80
Union Co.....	do.	1,300,000	1,187,284 74	8 10
Hawkeye Co.....	do.	348,000	365,819 40	9 45
Pittsburgh Co.....	do.	430,000	352,549 81	7 38
	Total,	2,365,000	$2,251,653 95	

This gives an average of 95 cents per square foot of ground 4 feet 6 inches high, and of $5.70 per cubic yard of gravel, which costs 47 cents per square foot, leaving a profit of 48 cents.

At Grass Flat, in Pioneer County, a branch tunnel, most of it 15 feet above the bed-rock, yielded:†

Sqr. ft. of tunnel.	Cubic yds. of gravel.	Total yield.	Per linear yd. of tunnel.	Per sqr. yd. of tunnel.	Per cubic yd. of gravel.
3000	475	$384.52	$2.3072	$1.1536	$0.8095

* Mining Commissioners Report, 1875, p. 155.

† Ibid, p. 156.

The main tunnel of the Pioneer Company's ground was run 1,186 feet in gravel from 10 to 20 feet above the bed-rock:

Sqr. ft. of tunnel.	Cubic yds. of gravel.	Total yield.	Per linear yd. of tunnel.	Per sqr. yd. of tunnel.	Per cubic yd. of gravel.
6616	883.37	$1,400.53	$3.56	$1.91	$1.59

The following table gives the product and rate per foot of channel for ten years of some of the leading mines of Sierra County, California;*

Mine.	Length of Location.	Yield per Foot.	Total Yield.
Union	2,400	$625 00	$1,500,000
Hawkeye	800	437 50	350,000
Pittsburgh	860	506 00	420,000
Monumental	1,040	312 00	325,000
Empire	1,560	482 05	752,000

An analysis of the cost of mining in a series of mines in McAdams and Indian Creek districts is appended. These mines are shallow workings, from 28 to 74 feet in depth, the shafts penetrating a light wash and tailings. The "pay" is quite regular, lying on and in the bed-rock, and is stoped out on the long-wall system, hoisted in buckets to the surface by horse-whims, and washed in sluices near the shaft mouths:†

Cost per Cubic Yard Mined.	Cameron Mine.	Carrol Mine.	Hardscrabble Mine.	Lincoln, Hart & Henry and Oak Grove Mines.	Siwash Mine.	Williams Mine.
Total cost of drift mining per cubic yard	$1.207	$1.629	$1.50	$1.634	$0.915	$0.89
Labor	0.952	1.148	1.00	1 148	0.66	0.552
Timber	0.15	0.316	0.31	0.316	0.15	0.164
Powder	.....	.....	.....	0.005	.....	.....
Lights	0.02	0.064	0.05	0.064	0.02	0.012
Falls	.....	.....	.....	.....	.....	0.036
Horse-feed	0.02	0.027	0.02	0.027	0 02	0.016
Incidentals and wear and tear	0.065	0.074	0.12	0.074	0.065	0.11

* Production of Gold and Silver in the United States, 1880, p. 325.

† Report of the United States Census for 1880, vol. xiii, p. 204.

The Hidden Treasure Company, on the Forest Hill divide in Placer County, owns 10,560 feet of channel. The tunnel is 2400 feet in length. The gravel is washed in sluices. The total expenses from 1878 to 1880 varied from 43 to 67 3-10 per cent. of the product. The contract price, for running the tunnel in soft slate requiring but little blasting, the timbers and track being furnished, is $3.50 per foot. The total expense, including the timbers and iron rails, is about $4 per foot. From this tunnel upraises are made every 125 feet to the gravel, which is blocked off in squares of that length of face. The channel is worked for a width of 500 feet. The pay gravel is 5 to 6 feet deep, and consists of quartz, pebbles and boulders, the latter sometimes being very large. The gold is 922 fine, and ranges in size from pieces of half an ounce down. About 60 men are employed as miners, who are paid $2.50 per day. All the wood used is cut by contract during the summer, 8 or 9 men being employed for the purpose. Twelve thousand timbers of all kinds and 80,000 feet of lagging are annually used. From 150 to 200 cars of gravel, or about 3500 pounds, are taken out of the mine daily. Ten men were formerly necessary to run the cars and do the same work which is now done by two horses and two men. One man is occupied washing the gravel, and several blacksmiths and carpenters are employed. The value of the gold taken out in 1880 was $115,000. The cost of doing it, for labor and superintendence, was $50,000; all other expenses $8,000; leaving a net profit of $57,000.

At the Mountain Gate mine the number of men employed is 45; 36 miners, 2 men at the water-wheel, 2 carmen, 2 blacksmiths, 1 carpenter, 1 gravel washer, 1 superintendent.

The following table gives the most important details of two of the claims at St. Andreas, Calaveras County, California:*

* Mining Commissioners Report, 1872, p. 72.

	Garnet Company.	Wilson & Co.
Inches of water used in sluice-washing	20	15.
Cost of water	$10.50 per week	$1.50 per day.
Supply of water lasting	4 months	5 months.
Depth of shaft	42 feet	33 feet.
Height of drift, on an average	4½ feet	6 to 10 feet.
Area of ground drifted upon	400 by 800 feet	300 by 70 feet.
Length of ground unworked on channel	1200 feet	900 feet.
Average of cement-gravel extracted per day	2500 pounds per man	2500 pounds per man.
Quantity of refuse (boulders) left in the drift	One-half	One-half.
Quantity washed in sluices per day (ten hours)		3 to 5 cubic yards.
Quantity of gold-bearing cement-gravel crushed in twenty four hours' run of five stamps of 500 pounds	18 tons or about 7 cubic yards.	
Crushed with heavy Chile arrastra	25 tons, or 10 cu. yds.	
Expense of milling, per cubic yd	70 cents (wages).	
Expense of extracting, per cubic yd.	$2.50	1 day's labor.
Yield of one cubic yd. of ground	$8.00	$5.
Total yield of claim in one year	$18,500.	$3000.
Wages paid underground-drifters	$2.50 per day.	
Number of men working	12	3.
Composition of deposit from surface downward	Lava, or sedimentary formation; hard cement above ledge or bed-rock; auriferous gravel-cement; hard quartz, black and dark colored.	Lava, gravel-cement, fragments of slate, granite and gneiss, rounded, loose sand.
Direction of channel	N.W., S.E.	N.W., S.E.
Bed-rock	Very hard, compact, gray quartz slate.	Slate, blue.

Owing to its peculiar nature very little improvement has been made in this method of mining since it was first invented. Drift-mining may be said to be confined almost exclusively to California and to have been developed there very slowly. It is on this account that so much less definite information has been published with regard to it than with regard to any other method of extracting gold in that country. Of all the methods of mining gold it has probably been less used and less studied. It is, however, more or less used in all the gold-mining regions of the State, and is likely in the future to attract more attention than ever. Such mines will always be numerous wherever the lava-capped channels are

found. The great difficulty about its development is the difficulty of finding the channel. Hundreds of tunnels, from a few hundred feet to several thousand feet in length, have been run too high to get at the rich gravel, or have missed finding it at all. On this account it is too uncertain to attract any very large amount of capital. It is not now carried on as extensively as during the period from 1855 to 1870, a large part of the easily accessible and best explored ground having been worked out. A great deal of the ground explored has been found too poor to work. At the present time Sierra, Nevada, Placer and Plumas Counties contain the most of the mines. The decision of the courts on the débris question has re-directed attention to this method, and its importance is daily increasing. About one-third of the gold credited to deep placer mining is now produced by this method, which is in use to some extent throughout the gold-bearing region of Central California, but only on a large scale in Placer and Sierra Counties, where the channels are covered to great depths. It is practiced to a very limited extent in some of the other Territories, but has not the same attractions there, or the same necessity for existence that it has in California. As we have seen, some of the California mines have yielded very large quantities of gold, but, as in every other case, the successes have been heralded everywhere, while the failures are known only within a very contracted area. It is, however, true that this kind of mining will yield, with the same amount of intelligence expended upon it, as fair returns for the capital invested as any of the other methods of gold mining.

The construction of long bed-rock tunnels at points where the channel has been demonstrated can always be done without risk. The width of the Blue Lead Channel varies from 300 to 600 feet. The portion which will pay by the drifting system is rarely narrower than 180 feet, and often wider than 300. At Bald Mountain it is 500 feet wide. If 200 feet is a fair average width of the pay gravel, and 4½ feet an average of height of the pay, there would be 165,353 cubic yards of ground for 5000 feet of location, equal to 230,706 car-loads of loose dirt. At $2.10 per car-load, which is somewhat under the value of gravel in this district, it would give a gross yield of something over half a million dollars for the 5000 linear feet of channel. The usual ratio of profit is about 50 per cent. The working life of mines of this kind is from 6 to 20 years, depending upon the length of the channel, the facilities for taking out the gravel and the number of men employed. When a

number of claims have been treated on a well defined channel which has been thoroughly explored, the claims are sometimes worked in rotation, the lowest one working first. When their ground is exhausted the next company works its ground, either by opening through a new tunnel, or by acquiring the right of way from the company who worked out the ground below. Occasionally there is no other way of working a claim except through the tunnel of the claim below. The number of men employed varies with the difficulty of breaking the ground, the quantity of water encountered in the working, the season of the year and the size of the claim. It varies from 10 to 15 to 150 and occasionally as high as 250 miners in each mine. The immense amount of country underlying the volcanic formations will furnish large quantities of gold for many years, and it will undoubtedly be one of the chief sources of gold supply in the future history of California.

This method resulted from necessity and not from choice. All these claims are situated in the higher ranges of the Sierra Nevadas, and are covered with hundreds of feet of basalt volcanic mud and scoria, and, as at Bald Mountain, capped with a table of basalt 100 feet or more in thickness. The process of drifting is the only one available for the extraction of gold, and, the cost being from one to two dollars per cubic yard, only the lower stratum can be profitably worked. The ordinary section of a drift claim would differ in no respect from that of an hydraulic bank, except that the volcanic matter covers the auriferous gravel in this case to a great depth. As in the hydraulic mining, the principal factor in the successful operation of these claims is either the ownership or the control of an abundant water supply at all seasons from a source sufficiently high to command large areas of ground, and a market for the sale of the water which is not required. Ordinarily, however, the drift companies do not own their own water; they purchase it.

COLOR-CONTRAST.

BY PROFESSOR O. N. ROOD.

We have a general belief that the colors of objects by which we are surrounded always present the same appearance, and tints or hues are constantly employed, for the purpose of furnishing information about a great variety of matters. Translating this into the

language of the undulating theory of light, one would say that we have a tolerably firm belief that the sensations produced in us by waves of light of certain lengths, will always be identical. In a rough way this notion is correct; objects seen under similar illuminations and with average surroundings, do cause about the same sensations in the beholder. But the color of the adjacent surfaces, the color of the immediate environment, has an extraordinary influence on the sensation produced in us by any selected object, particularly if its color be not highly pronounced; place it on one background and we call it red, transfer it to another, and it seems green, while on a third it makes the impression of being yellow. I recall the case of a house, with the color of which I was quite familiar; the hue was what might be termed red-gray, the red element being sufficiently distinct. I had never seen the house except in summer when it was surrounded by green fields and green trees, but one winter when I visited the place, snow-clad, it turned out that the real color of the house, independently of its surroundings, was almost pure gray, the red element having been added to it by contrast due to the green landscape. It is indeed almost impossible to ascertain accurately, by mere inspection, the real colors of objects which we cannot detach from their surroundings. Even, in the case of paintings the real color of each patch is different from what it appears to be; the picture is built up with the aid of illusions piled on illusions, and it is good, very much in proportion to the quantity of color deception contained in it. The misleading appearances presented by a real landscape are even more numerous and more effective; the beholder may gaze on the scene for ten minutes (the longest time that people not artists ever look at landscapes), and go away without having made out the real color of a single one of its fragments. It would appear, then, as a matter of fact, that the color impressions produced by objects are variable, shifting according to circumstances, even reversible, and interchangeable. The size of objects, their weight, structure, power to conduct heat or electricity, to transmit and reflect light, would remain just the same if there were no living beings on the globe, but their colors would instantly cease to exist. What we call the colors of objects are merely certain sensations that they produce in *us;* outside and apart from life these sensations have no existence, and the waves which are capable of exciting them, remain mere mechanical movements, like those which ruffle the ripe harvest

fields or toss the ocean waves. What we call the colors of objects being then only effects produced on our consciousness by waves of light, it is not strange that they should be subject to fluctuations. At this point an interesting question might be asked: the external exciting causes being the same, will the sensations produced in different individuals be at all alike in kind, and of similar intensity? Of course, this cannot be answered with absolute certainty, but the balance of probability is that the sensations are similar in kind, but differ in intensity. Some persons with delicate organizations are *literally* nauseated, by looking intently for a few moments at a large surface painted with artificial ultramarine-blue, and I once knew a young man who spent some time in examining a colored drawing, and then calmly asked whether it was entirely executed in sepia—he was not color-blind, and he had worked in sepia; his color perceptions were certainly slow and probably dull. We may also make another inquiry: in one and the same individual, external exciting causes remaining constant, how far will the resulting color sensations remain the same in quality and in strength. The reply to this can be given with more confidence: in normal conditions of the same person the sensations appear to be mainly identical in kind, but they may vary considerably in intensity. That is to say, the *relations* of the color sensations produced by a set of objects remain tolerably constant: the sets of colored worsteds that are arranged to-day in a system, will appear to-morrow to be rightly placed, though they may all look rather dull in hue. A set of colored objects arranged systematically, so that adjacent colored surfaces differ as little as possible, so that all changes proceed gradually, will bear simple relations even to the external exciting causes, they will vary in position with the length of the waves of light coming from them. From this it appears that although color sensation is as different as possible from the mechanical movements of waves of light, yet that it is possible to arrange our sensations in a system based on the lengths of these waves.

Under the term contrast is included a set of peculiar actions, readily brought into play, which lead us to assign to colors false positions in systems like that just mentioned. Contrast really alters our color sensations, or in mild cases, our judgment of them. The subject has been divided into two portions: successive and simultaneous contrast. Certain recent experiments of the author

have inclined him to believe that the division is artificial and unnecessary, but in the present article it is not worth while to insist on the point. Experiments on successive contrast are easily made; a few brightly colored sheets of paper should be procured, also some that are gray and black. One of the easiest is the following: a small slip of bright green paper is placed on a sheet of gray paper, and after looking attentively for a number of seconds at the small green piece, it is to be suddenly jerked away by a thread, when it will be found that it is replaced by a rose-colored ghost, which will presently vanish. In this experiment, for a few seconds, light which is really white or gray, produces the sensation of red. The main point to be attended to in the manipulation is, the *instantaneous* removal of the green slip; it is also well not to try to look at it as a whole, the attention being rather directed to a small mark placed at its centre. The after-image, the rose-red, is complementary to the original agent producing it, to the green; that is, if mixed with the green, would produce the sensation that we call white. If slips of other colors are used, complementary after-images will also be generated, but they will fall behind the rose-red in strength. Sometimes they fail to appear, but this is mostly due to the rudeness of the apparatus, for if the small slip be very quickly withdrawn without the observer being able to see how it is done, effects can be produced even with colors as dull and undecided as that of freshly planed pine wood. The observer must not *see* what is done, but curiously enough, his knowledge of the process in all its details is of no consequence whatever. If colored paper is used as a ground in these experiments instead of gray, the resulting image or ghost has a color made up of the complementary color of the small slip mixed with that of the ground. An apparatus was contrived by the author for measuring the intensity of these after-images; only a few experiments have thus far been made with it, but they go to show that the intensity of the after-sensation is independent of the age of the person experimented on; how it will vary in different conditions of health remains to be determined.

The most generally accepted theory of these phenomena is, that they depend on the fatigue of the retinal elements; for example, in the case of the green slip, what we may call the green nerves, become more fatigued than their companions, and hence are not fully up to the mark when white light (gray) is presented; the resulting

sensation is then, that of white light minus green light, which we know from other experiments to be purplish-red.

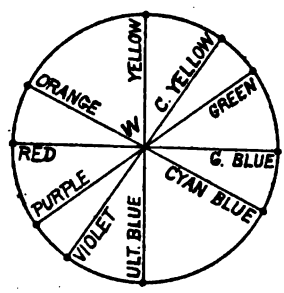
These experiments on successive contrast are interesting as bearing on the theory of the subject, but they are rather artificial, at least they take place under conditions that are not very common in our daily life. Just the reverse is true of simultaneous contrast; in any ordinary or natural arrangement of colored objects, its action always makes itself felt, often quite powerfully, and we are compelled to adopt highly artificial procedures to rid ourselves of its influence. Experiments can easily be made on this second variety of contrast if in addition to the colored papers above-mentioned, we add some that are dull and undecided in hue. The various kinds of wrapping paper that go under the name of brown, answer quite nicely, and it will be well to procure a few sheets of gray, or what is sold to artists under the name of gray-paper, the real tints being quite manifold, but all more or less grayish. Small slips of pure gray paper or of tinted gray paper when placed on intensely colored grounds, can be made to assume almost any hue, and similar effects are produced even when the color of the ground is not at all strong. Slips of colored paper, even when placed side by side alter each others' colors, often to an incredible degree; they affect each other also when at some distance. The pale or subdued colors, so commonly found in nature are much more subject to these changes than those that are strong or intense. A description of the experiments that can be made would be out of place here, and would convey no idea of the illusions that are readily produced, illusions from which no effort of the reasoning powers can free us. The same slip of paper may be made to tint itself successively with all the colors of the spectrum, and to continue thus tinted as long as the conditions remain unaltered. The paper may also have its apparent luminosity greatly changed; it may be made to look beautiful or ugly, clean or dirty, and even colored papers may be made to appear white. Meanwhile there is no strain on the eye, and no more perception of fatigue than in its ordinary use. The phenomena that present themselves correspond closely with those of successive contrast, and are probably due to the same cause, viz.: to a minor degree of fatigue of the retinal elements. There are some cases of simultaneous contrast mentioned by Helmholtz that seem to depend solely on a deception of

the judgment, and it is possible that this may always be a factor, adding to the effects due to fatigue.

In paintings the illusions of simultaneous contrast are constantly employed by skilful artists, and in a good picture not a single patch of color is seen with its real hue; it consists of illusions piled on illusions. The same is true of a landscape or of any scene in nature, and it is true even of the coloring of a single face. The beginner in art learns all this practically and painfully; it is only after years of labor that he discovers how to penetrate the veil cast by contrast over nature, and also in his measure to use it. Contrast always alters the appearance of a set of objects; the alteration may be helpful to them, it may make their colors appear richer and more luminous, or it may degrade them into dull, dirty, disagreeable stains. It may be asked, "If you wish your colors to look rich, why not paint them at once a little richer and pay no attention to contrast?" The answer is to be found in cheap, bad chromo-lithographs where all the colors are exaggerated, only with the result of giving them an air of offensive vulgarity. It appears to be necessary that the colors in a painting should, to a great extent, owe their richness to contrast—to an illusion. And it is not admiration of magical work that carries the day and makes us pronounce in favor of one painting rather than another, for people who are quite untrained in art are similarly affected. Colors that are well contrasted seem to have over them a kind of shimmer, a soft radiance that greatly adds to their beauty and is suggestive of something ethereal. This effect is probably due to the fact that the contrast action is somewhat fluctuating, and that the sensations produced by it are subject constantly to small variations; as artists say: "The colors have life; are not cold and dead," *i.e.*, motionless. This shimmer lends itself readily to the reproduction of scenes from nature; we forget the presence of the canvas with its pigments and penetrate beneath its surface, travelling in imagination miles into the distance. In work that is purely decorative, where we are content with surfaces, simultaneous contrast plays an important part, and gives a strange beauty to colors that apart by themselves are dull and insignificant. That the effect is keenly felt by many savage races, is shown by the admirable use of contrast in many of their designs.

Some time ago after numerous experiments, the author constructed a geometrical diagram for the solution of qualitative problems in contrast; it enables us by mere inspection to predict the effect that will be produced by bringing any one color into competition with all colors successively. In the first place we imagine that the most intense colors at our disposal are arranged on the circumference of a circle, as indicated in Fig. 1, complementary colors, or those that by mixture produce white, are opposite each other at the extremities of the same diameter. The interval on the circumference between any two marked points is supposed to be filled with a properly graduated set of hues; for example, between red and orange all varieties of orange-red and red-orange are located. At the centre we imagine white to be placed, or

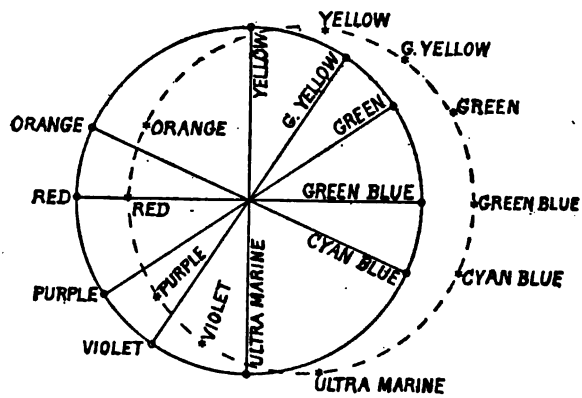
FIG. 1.



rather a gray, such as would be produced by the mixture of any pair of colors situated on the circumference. As we advance along any radius toward the centre, the color is supposed to become more grayish, until the centre is reached, where we encounter pure gray. Along any one radius the luminosity is supposed to remain constant. This arrangement constitutes a variety of the well-known chromatic circle, and any point situated within it will represent a color that will be defined with regard to hue and intensity or saturation. Points lying outside of the circle will have a greater degree of saturation, or be more intense than those on the circumference, just in proportion to their distance from the centre. To study the effects of contrast, two identical chromatic circles are traced on paper; one of them is cut out, rendered transparent and placed over its companion, its centre being shifted more or less. Let us suppose that it is desired to ascertain the effect produced by

red on all the colors and also on the red itself; we move the upper circle so that its centre is shifted as indicated in Fig. 2, and then transfer the points marked red, orange, yellow, etc., on the upper circle, by pricking with a pin, to the lower circle; these pin-marks on the lower circle will indicate the change produced on all the colors by competition with red. The stars on the dotted circle represent the results. We find that red when contrasted with greenish-blue, its complement, causes this color to move outside of the circumference on a prolongation of its own line, and we know consequently that greenish-blue is not made more or less blue or green, but is simply caused to appear more saturated or brilliant. The new point for red lies also on the same diameter, but is nearer

FIG. 2.



to the centre of the circle; that is, red, when contrasted with red, appears duller or less saturated. Proceeding with the examination of the effects produced on the other colors, we find that orange has been moved towards yellow and also towards the centre of the circle; hence the diagram tells us that red, when put into competition with orange, causes the latter to appear more yellowish and at the same time less intense. The intensity of yellow is not much affected, but it is made to appear more greenish. Green is made to look somewhat bluish and more brilliant. The changes produced by red on the other colors are left for the reader to trace out. If we wish to study the effects produced on the colors of the chromatic circle by contrasting them, for instance, with yellow, we have, of course, merely to displace the upper circle along the line

joining yellow with its complement ultramarine-blue, and then proceed as before. It is evident that the indications given by this diagram will not correspond with the facts, unless the colors are rightly located on the circumference, and it was necessary to make many experiments to settle this matter.

The results given by the diagram, however correct they may be, are, like actual experiments with colored surfaces, only qualitative; with its aid we can tell in which direction the color is shifted, how its hue and intensity are affected, but we do not know except quite roughly, *how much;* the quantitative element is absent. More than a year ago the author undertook a series of experiments for the purpose of measuring quantitatively the changes which colors undergo through contrast, or for measuring accurately the fluctuations in our sensations owing to its operation. In a matter as difficult as this, of course the simplest cases were selected for study, and the effects produced on pure gray, by red, green and blue-violet were examined; that is, the relative power of these colors to produce retinal fatigue was measured. It turned out to be possible to determine and to express in figures these effects for the surfaces selected, *viz.*, for vermilion, emerald-green and artificial ultramarine-blue, but then the still more difficult problem remained, of finding out whether these painted surfaces had corresponding intensities, or could properly be said to be situated on the circumference of the same chromatic circle. With old methods of experimenting this problem is insoluble; the old methods give us with certainty and ease the relative intensities of any pair of complementary colors; that is, with their aid the position of any number of colors situated on the same diameter can be determined, but nothing more. The older methods are founded on the idea that it is only possible for us to compare sensations that are strictly alike, and that we can balance and weigh different colors only when they are truly complementary. But by mixing colors that are not quite complementary, and noticing when the best *approximation* to gray is produced, it was found possible to crawl gradually by zig-zags around the chromatic circle, and establish relations between any set of colored surfaces. Of course, in this mode of procedure the probable error of any set of observations is larger than with the old method; it is more necessary to increase the number of experiments and to adopt means of control, and the observer must be better trained. But then it is to be remembered that almost all

the methods of observation in actual use in the different departments of physics, are particularly easy; as a distinguished physicist once remarked to the author, "It is hard to plan a research; hard to set up the apparatus and get it to work; but when this is done, almost any one can make the observations." The final result of these experiments with red, green and blue was, that the retinal fatigue ran as 1, 4, 6, or that the power of these colors to affect others in their neighborhood was in the ratio of these numbers. This conclusion is quite in harmony with our qualitative experience, and also corresponds not badly with the relative difficulty that artists have in handling these colors, particularly if we take into account the fact that the relative intensities of vermilion, emerald-green and artificial ultramarine-blue are as 1, 1.7, 0.53, as was determined in the course of the research. Green is the color that really gives artists the most trouble, although it produces less retinal fatigue than a corresponding blue; but then artists have at their disposal green pigments that are three times as intense or saturated as their strongest blues.

All the broad principles that hold good in color-contrast are also applicable to cases where we deal only with light and shade. Here the apparent *luminosity* of a patch is raised or lowered at the will of the artist, who again deals with illusions, and is successful in proportion to his power to produce and vary them. Both these departments have one element in common; both deal with surfaces. But there is a variety of contrast that plays an important part in mere outline drawings; curvature is set off by straightness, jagged angular lines by rounded; lines that are definite in purpose by those that are more careless, and these again by lines apparently meaningless, representing nothing in particular. Mere scratches, if they come from an artistic hand and are rightly placed, will have a beauty, partly due to contrast, that is instantly recognized by the educated eye.

In all departments of art, contrast of one kind or another enters in as an important element; in music and oratory it makes itself powerfully felt; even in ordinary conversation it has great weight, and insensibility to its laws makes the talk sound either jerky and irritating, or dull and monotonous. The celebrated talking-machine of Faber, being created without a soul, spoke of course without

any attention to this matter; the loud clear voice pronounced all its words in exactly the same tone, without any instinctive modulation; the effect was horrible; one instantly thought of a terrible dead man suddenly galvanized into a mockery of life. The manipulator of the apparatus was fully occupied in making it speak machine-fashion, and had neither time nor power to attend to any of the details of vocal contrast.

CONCENTRATED ROLLING LOADS.

BY R. W. HILDRETH, E.M.

THE object of this article is primarily to describe a method of determining the strains in bridge members, due to concentrated rolling loads.* The attention of the writer was called to this method by an engineer, formerly connected with the Northern Pacific Railway, and, in the same or some similar form, it is probably known to many engineers. There is nothing new in principle involved; the method being simply the collection of partial results of calculations, that must necessarily be made, into a form convenient for use, thereby saving repetition of work. A secondary object is a description, in the principal cases, of the positions concentrated loads will occupy, when the strains produced are a maximum.

The chief advantages of the method described appear where there is more than one structure to be designed, using the same live load for each. This is the case in all railway offices that design their own bridges and trestles.

Even, in the case of but one structure and a uniform live load, it will probably be found advantageous to adopt this method. Its chief use is for small spans, plate-girders and the floor-system of all spans; these being, in point of fact, the only cases where it is important to subdivide engine loads into their component parts.

---

* The originator of the method is not known to the writer, but is thought to be Mr. Theodore Cooper.

To the kindness of Mr. Alfred Noble, Mem. Am. Soc. C. E., is also due the weight of the standard consolidation engine used on the North Pacific Railway, and given with this article.

The method consists, in a general way, of writing on a transparent piece of paper, the weights and other data hereafter described, at distances apart, proportional to the actual spaces between them. This paper, which we will call the "movable diagram," is used for determining strains, by placing it over a skeleton drawing of the structure, conveniently termed the "fixed diagram," and, by properly placing the former over the latter, for each part of the structure considered, a portion of the necessary work of calculation is saved, by reading directly from the movable diagram. The two diagrams must be to the same scale, the movable being retained for use on all structures subject to the same live load.

In preparing the movable diagram, a scale is first selected; that of one-third of an inch to the foot, found on all decimal scales, is probably the most convenient for spans up to eighty or ninety feet. Then, at proper distances apart, the weights are represented by circles: above each circle is written, in its proper line, the weight at that point; the sum of all the weights up to and including that weight; and the sum of their moments about the point in question, as a centre. The distance from every weight to the next is written between the circles and under each is placed its distance from the first weight of the system.

At proper points it is convenient, where the diagram is to be frequently used, to have the centres of gravity indicated by G_1, G_2, etc., G_5 being, for instance, that of all weights up to and including the fifth; above these points it is well to write their distances from the first weight.

Fig. 1 shows such a diagram, in which these various quantities are algebraically represented. Assuming the notation of this figure, the various centres of gravity will evidently be given in distance from the first weight, by the following formula:

$$G_n = d_n - \frac{\Sigma_1^{n-1} m}{\Sigma_1^{n} \omega}.$$

The line of total moments is easiest filled in by the following consideration, proved similarly to equation (1), page 319:

$$\Sigma_1^{m-1} m = \Sigma_1^{m-2} m + \Sigma_1^{m-1} \omega \times a^{m-1}.$$

By completing, first the lines of total distances and total weights, that of total moments may then be easily written by commencing

at the first weight and using the formula successively for each. Lastly, the distances of the centres of gravity from the first weight may be determined.

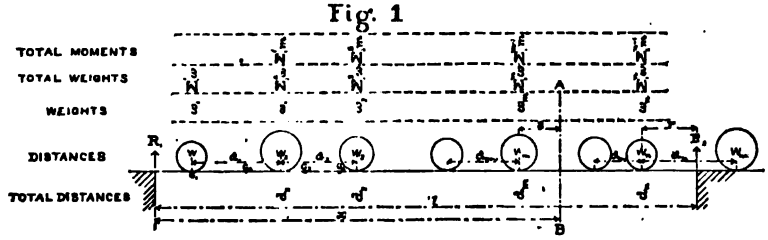
In applying this diagram, the loads will be assumed to come on the structure from the right, the reaction of the left abutment will be represented by R_1, and that of the right by R_2, and, when reaction is spoken of without qualification, that of the left abutment will be understood.

Application of the Movable Diagram.

Assume Fig. 1 to be placed over the fixed diagram of a beam, whose span is indicated in the figure; let W_n be placed at any distance r from the right abutment. Let it be required to determine the shear and bending moment at any section AB, distant x from the left abutment.

Some weight W_m will be at, say, a distance s to the left of AB.

Fig. 1



Represent the span by l and the shear and bending moment in AB by S and M. Then we have

$$l \times R_1 = \omega_1(d_n + r) + \omega_2(d_n - d_2 + r) + \text{etc.} \ldots$$
$$\omega_{n-1}(d_n - d_{n-1} + r) + \omega_n r.$$
$$= \Sigma_1^{n-1} m + r(\omega_1 + \omega_2 + \text{etc.} \ldots \omega_n).$$
$$= \Sigma_1^{n-1} m + r \times \Sigma_1^{n} \omega. \quad \ldots \quad (1)$$
$$R_1 = \frac{\Sigma_1^{n-1} m + r\Sigma_1^{n} \omega}{l}. \quad \ldots \quad (2)$$

Then $S = R_1 - \Sigma_1^{m} \omega$. $\ldots$ (3)

And $M = xR_1 - (\Sigma_1^{m-1} m + s\Sigma_1^{m} \omega)$. $\ldots$ (4)

The terms of these equations can all be taken directly from the movable diagram.

If for any position, some weights are to the left of the left end

of the beam, they must be omitted from consideration, as follows: if $\Sigma_1^d\omega$ is their total weight, mR their combined moment about the right abutment, and m_m that about the weight W_m, then (2), (3), and (4) become: $R_1' = \frac{\Sigma_1^{n-1}m + r\Sigma_1^n\omega - m_R}{l}$; $S_1 = R_1' - (\Sigma_1^m\omega - \Sigma_1^d\omega)$; and $M' = xR_1' - (\Sigma_1^{m-1}m + s\Sigma_1^m\omega - m_m)$.

As the plane AB is usually taken to coincide with some weight as W_m, the values of the shear and bending moment then become:

$$S = R_1 - \Sigma_1^{m-1}\omega; \text{ and } M = xR_1 - \Sigma_1^{m-1}m.$$

POSITIONS OF THE LOAD GIVING MAXIMUM STRAINS IN A BEAM.

I. Maximum Shear at any Point.

The greatest shear will always be under some weight. Referring to Fig. 1, it is evident that the shear is increased by advancing the system from, say, W_m over AB to W_{m+1}, over AB, when $\omega_m < \frac{a_m}{l}\Sigma_1^n\omega + \frac{t}{l}\omega_{n+1} + \frac{t'}{l}\omega_{n+2} +$, etc.

where t and t′ are the distances of W_{n+1} and W_{n+2} from the right abutment when W_{m+1} is over AB, provided these weights come on the beam. This test indicates, by failing to hold good, the weight which should be placed over the point to produce the greatest shear. It is, of course, applied to the weights successively, commencing with the first.

II. Maximum Bending Moment at any Point.

Let M_{m-1} and M_m be the bending moments produced under W_{m-1} and W_m when these weights are over the section AB (see Fig. 1), and other symbols be as before, R_1 being the reaction when W_{m-1} is over AB. Then will

$$M_{m-1} = xR_1 - \Sigma_1^{m-2}m;$$

$$\text{and } M_m = x(R_1 + \frac{a_{m-1}}{l}\Sigma_1^n\omega) - \Sigma_1^{m-1}m;$$

$$M_m - M_{m-1} = a_{m-1}x\frac{\Sigma_1^n\omega}{l} + \Sigma_1^{m-2}m - \Sigma_1^{m-1}m;$$

$$\text{but } \Sigma_1^{m-2}m - \Sigma_1^{m-1}m = -a_{m-1}\Sigma_1^{m-1}\omega.$$

$$\therefore M_m - M_{m-1} = a_{m-1}(x\frac{\Sigma_1^n\omega}{l} - \Sigma_1^{m-1}\omega).$$

M_m is greater or less than M_{m-1} as $x \frac{\Sigma_1^n \omega}{l}$ is greater or less than $\Sigma_1^{m-1}\omega$, or what is the same thing, as x is greater or less than $\frac{\Sigma_1^{m-1}\omega}{\Sigma_1^n \omega} l$. That is, for all values of x greater than $\frac{\Sigma_1^{m-1}\omega}{\Sigma_1^n \omega} l$, a greater moment will be produced at the point by W_m than by any weight that comes before it; similarly, at the point $x = \frac{\Sigma_1^m \omega}{\Sigma_1^n \omega} l$, W_{m+1} produces equal moment with W_m, for less values it produces less, and for greater values a greater moment. For any value of x between $\frac{\Sigma_1^{m-1}\omega}{\Sigma_1^n \omega} l$ and $\frac{\Sigma_1^m \omega}{\Sigma_1^n \omega} l$, there will be produced a greater moment at the point, for W_m over it than for any other weight.*

III. Maximum Bending Moment under any Weight.

Let the symbols be as before, except that for W_m over AB let the reaction be R_1 and the moment in AB be M_m, and let h_m equal the distance of the centre of gravity of the system from the weight W_m; that is, $h_m = G_n - d_m$.

Assume the system to be moved a distance n, and let the new moment under W_m be M_m'.

$$\text{Then } M_m = R_1 x - \Sigma_1^{m-1} m;$$

and remembering that n is negative or positive according as the motion is to the left or to the right;

$$M_m' = (R_1 - \frac{n}{l}\Sigma_1^n \omega)(x + n) - \Sigma_1^{m-1} m \quad . \quad . \quad . \quad (5)$$

$$= R_1 x - \frac{n}{l} x \Sigma_1^n \omega + n R_1 - \frac{n^2}{l} \Sigma_1^n \omega - \Sigma_1^{m-1} m.$$

In order to find how far from its first position the system must be moved, for the moment under W_m to be a maximum, we have, differentiating with respect to n;

---

* The first demonstration of this is credited by Professor Du Bois, in his "Strains in Framed Structures," to Professor Alexander, of the Imperial College of Tokio, Japan.

$$\frac{dM_m'}{dn} = R_1 - \frac{\Sigma_1^n \omega}{l} x - 2\frac{\Sigma_1^n \omega}{l} n = 0;$$

$$\therefore n = \tfrac{1}{2}\left(\frac{R_1}{\Sigma_1^n \omega} l - x\right) \text{ when } M_m' \text{ is a maximum.}$$

If the first position was such, that the centre of gravity of the system was at the middle of the span;

$$\text{then } R_1 = \frac{\Sigma_1^n \omega}{2}; \text{ and } x = \tfrac{1}{2}l - h_m;$$

and we would have, $n = \tfrac{1}{2}\left(\frac{l}{2} - x\right) = \tfrac{1}{2}h_m$. That is, the maximum moment under any weight is when the centre of gravity of the system and that weight are on opposite sides and at equal distance from the middle of the span.

The value of this maximum moment is, by substituting in (5),

$$(M_m)_{max} = \frac{\Sigma_1^n \omega}{l}\left(\tfrac{1}{2}l - \tfrac{1}{2}h_m\right)^2 - \Sigma_1^{m-1} m;$$

but $\tfrac{1}{2}l - \tfrac{1}{2}h_m$ is the value of x at which the maximum moment under W_m is produced. Let this value of x be b_m, *i.e.*, $b_m = \tfrac{1}{2}(l - h_m)$.

$$\text{Then, } (M_m)_{max} = \frac{\Sigma_1^n \omega}{l} b_m^2 - \Sigma_1^{m-1} m. \quad . \quad (6)$$

These points are clearly brought out in Fig. 2. This shows graphically the moments produced in a beam of twenty-five feet span, by a system of five weights under all conditions of loading. The weights were taken (see Fig. 1) ω_1 as five, ω_2 twenty, ω_3 fifteen, ω_4 thirty-five, and ω_5 as twenty-five tons, and their distances apart a_1, a_2, etc., as respectively two, five, three, and six feet.

The points F_1, F_2, etc., of Fig. 2, divide the beam into *fields*, such that each field is proportional to the corresponding weight, *i.e.*, the fourth field is equal to $\frac{\omega_4}{\Sigma_1^5 \omega} l$, or the point F_4 is at a distance from the left abutment equal to $\frac{\Sigma_1^4 \omega}{\Sigma_1^5 \omega} l$.

The irregular curve $a_1 a_1$ represents the moments produced at each point when W_1 is over that point, the curves $a_2 a_2$, $a_3 a_3$, etc., are

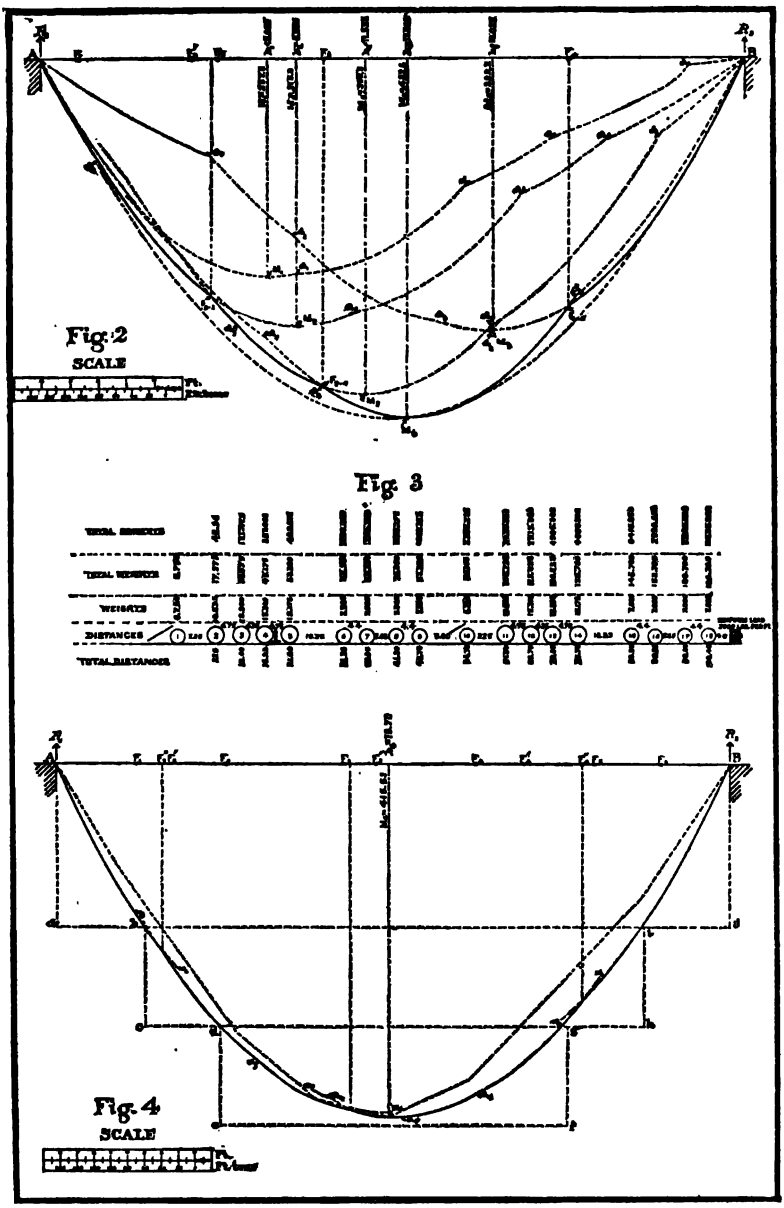


Fig. 2
SCALE
Fig. 3
Fig. 4
SCALE

similar ones for W_2, W_3, etc., the letters being placed at points where the curvature changes, due to the coming on or going off of weights.

There are two points to be noted about these curves: first, that each attains a maximum equal, in the figure, to M_1, M_2, etc., distant from the left abutment b_1, b_2, etc., previously determined by formula. The curve corresponding to the weight nearest the centre of gravity of the system, in this case a_4a_4, has its maximum ordinate greater than that of any other curve; and this is usually the case, especially with actual engine loads. Second, that each crosses and becomes greater than its predecessor at the boundary of its field, except the curves a_2a_2 and a_3a_3. The exceptions are caused by W_1 leaving the beam before W_2 arrives at F_1 or W_3 at F_2.

In general, none of the results determined by formula for a particular point apply, unless the conditions assumed are such as actually exist when the proper weights are at that point. The remedy for such cases is a redetermination of the result under the changed conditions.

It frequently happens in determining the point of intersection of two successive curves, that no point can be found, by the rules given, at which the conditions will be for either weight over the point, the same as those assumed in fixing its position. In this case the following consideration enables the intersection to be predicted as occurring between two points or not at all. It is evident, that when a curve of greater ordinates approaches the point where intersection with a curve of lesser has been determined to take place, and the loading for the first curve changes from that assumed in fixing the point, then the intersection, if at all, will occur *beyond* the point first determined.

In the case of $a_2\ a_2$ about to intersect $a_1\ a_1$ at F_1, W_1 passes off before W_2 reaches F_1, this throws the intersection to the *left*, and it cannot take place at all, W_2 now being the first weight. Similarly the intersection of $a_3\ a_3$ with $a_2\ a_2$, determined at F_2, will occur further to the *left*, from the same cause; F_2' is then determined, assuming W_1 not to exist; this assumption is correct for W_3 at F_2' but not for W_2; now considering the direction of motion reversed and a_2a_2 about to cross $a_3\ a_3$ at F_2', W_1 comes on the beam before W_2 reaches F_2', this indicates that intersection will be to the *right* of F_2' and therefore between F_2 and F_2'.

By this method of reasoning, using the movable over the fixed diagram, the boundaries of the various fields can be first located, either exactly or approximately, and then the curve of maximum moments, shown in the figure by full lines, can be drawn, by taking for each portion of the span the weight that it is known will produce the greatest moments there, and determining a sufficient number of points to sketch in the curve.

The values of the moments are, of course, easiest determined by using the partial results, found on the movable diagram, as previously indicated. Fig. 4 shows such a maximum curve for a girder of forty feet span, subject to strain by the standard consolidation engine load of the Northern Pacific Railway, shown in Fig. 3; this latter figure is drawn as a movable diagram for the standard load, but is not to the same scale as Fig. 4. The values of Fig. 3 are all in tons and feet.

In Fig. 4 the curve of W_5 crosses that of W_4 at F_4'' the third determination of the intersection, that of W_4 intersects that of W_3 between F_3 and F_3' and that of W_3 becomes greater than that of W_2 between the second and third values of F_2.

A curve, which will be at all points greater than any possible moment that the assumed load can produce, will evidently be portions of the above maximum curve, united by tangents between those parts belonging to adjacent weights; because, for any one position of the load, the moments are equal to ordinates to straight lines connecting points on the proper curves directly under the weights.

As the construction of such a curve of maximum moments is tedious, and as variations in the engines used will change such a curve considerably, it would in most cases seem to be better to adopt some uniform load that will give greater moments at all points. A uniform load, such as gives at the same point a moment equal to the greatest moment produced by the heaviest engine, naturally suggests itself; the difficulty is, that this load does not necessarily produce at all points moments greater than those produced by the engine load. In most practical cases, however, this curve of uniform loading will at points pass inside the curve of actual maximum moments, by only a small amount. Were the heaviest weights at some distance from the centre of gravity of the load and separated by smaller weights, this difference would be

more marked; in actual engine loads the reverse of this supposition is the case.

In Fig. 2 the dotted parabola passing through M_4 corresponds to a uniform load of 5.43 tons per foot, and a similar one for Fig. 4 would be due to 2.08 tons per foot. In the latter figure the parabola would coincide so closely with the actual curve, that it was not indicated.

The dotted polygon in Fig. 4 is that of the moments produced, for the load in the position giving the maximum moment M_4. It is this polygon that is frequently used for determining the number and size of cover-plates in plate-girders, etc., and the figure shows that this diagram might give plates shorter than actually needed.

If a more rapid method than that of determining the actual curve of maximum moments is desired, that of assuming a uniform load, based on the maximum moment, due to the heaviest engine, is recommended.

Using symbols as before:

$\frac{2(M_m)_{max}}{lb_m - b_m^2}$ = the equivalent uniform load;

$M = (M_m)_{max} \times \frac{lx - x^2}{lb_m - b_m^2}$ is the equation of the moment curve;

and $(M_m)_{max} \times \frac{l^2}{4(lb_m - b_m^2)}$ = the moment at middle of span.

The weight to be taken as W_m, may be quickly determined by trial, and, as before stated, is generally the one nearest the centre of gravity of the heaviest combination of weights that can be brought on the span.

Instead of increasing the resulting live load strains to allow for impact, the equivalent uniform live load may be multiplied by the proper factor for this purpose, and the uniform dead load added to the result. The resulting total uniform load may be used in the ordinary way, for determining flange sections and lengths of cover plates.

IV. Maximum Weight at Panel-Points of Trusses.

The position of the load that gives the maximum weight on transverse floor-members of bridges or at panel points, is such that there is a weight over the point, and any movement of the load in either direction will be moving a greater weight away from,

than towards, the point, the load on two adjacent panels alone being considered.

This is evident from the fact, that the movement of the load through a distance n, increases the weight or reaction at the point by $\frac{n}{l}$ times the total weight moving towards, and diminishes it by $\frac{n}{l}$ times the total weight moving away from, the point; l being the length of either panel. The weight to be placed over the point is determined by taking one-half of the total weight on two adjacent panels, noticing between what two values the result comes in the line of total weights on the movable diagram, and placing over the point, the nearest weight on that side of the movable diagram where the sum of the weights is the greatest.

Strains in Trusses.

In determining the strains in a truss, a movable diagram can be made for the uniform live load, with total moments, total weights, etc., at distance apart, equal to the panel length, and the resulting strains determined; then the engine excess may be assumed as concentrated at the proper panel points, and the strains so found may be added to those due to the uniform load. If it is desired to use actual loads, the movable diagram may be as for plate-girders, etc., and the uniform load behind the engines may be considered as concentrated at distances apart equal to the spaces between trucks of the cars giving this assumed uniform load. In the latter case, the positions of maximum strain may be found by trial, or conditions can be determined, the fulfilment of which will give such positions directly.

GEOLOGICAL NOTES. (I.)

BY PROF. J. S. NEWBERRY.

The Great Falls Coal Field, Montana.

The falls of the Missouri are situated in a picturesque and productive region, in northeastern Montana. A rolling prairie covered with rich grass stretches away like the sea toward the east and north; on the south a few miles distant are the Highwood and Belt Mountains, outlying ranges of the Rocky Mountain system,

having the same geological structure, viz.: granitic axes, on the flanks of which rest Cambrian rocks, and above these the Potsdam sandstone and Silurian limestones. Toward the west the view is bounded by the main range of the Rockies, generally high with many picturesque summits. All these mountains are heavily timbered and through wooded gorges numerous tributaries of the Missouri issue into open valleys, now generally cultivated, separated by broad, undulating divides, formerly the favorite pasture grounds of the buffalo. The buffaloes are gone, but their trails and bones are seen everywhere. The valleys leading up into the mountains, however, abound in game, and the streams in fish, beyond any other part of the continent known to me. The surface of the country about the falls is occupied by a thick sheet of glacial drift, but the underlying rock is exposed at the falls which are a series of cascades having an aggregate altitude of about 200 feet. The rocks which form the falls are alternating sandstones and shales of a prevailing reddish tint that form the upper members of the Great Falls coal series. These beds rise southward on to the lower slopes of the Belt and Highwood Mountains. A few miles from the river, in the valley of Belt Creek and in Sand Coulée important coal beds are exposed. Of these, one is twelve to fifteen feet in thickness, but like most such seams, is composed of several benches differing somewhat in quality. The lower bench, about two and a half feet in thickness, makes a fairly good coke; the other benches are serviceable fuels but are a little more slaty. In a somewhat careful examination of these coal beds made two years since, I was unable to find any fossils by which their age could be determined. Some years before Dr. F. V. Hayden, and later, Dr. C. A. White visited these coal mines, but were no more fortunate than myself in the effort to obtain fossils; and so the question of the age of the coal basin has until now remained an interesting but unsolved problem.

A few months since, Mr. J. J. Hill, General Manager of the St. Paul and Manitoba Railroad, and who is now constructing a branch line to the Falls of the Missouri, sent to me a slab of sandstone from Sand Coulée of which the surface was covered with impressions of Unios, but they were too imperfect for determination and left the age of the coal field still undecided. Within a few weeks, however, the evidence which I have so long craved has been furnished me by Mr. R. S. Williams, a botanist living at Great Falls.

In a railroad cut five miles above the mouth of Sun River he has obtained a number of ferruginous concretions, each one of which contains a leaf or twig beautifully preserved. Though only a small number of these plants have yet reached me, such as could be sent by mail, they are decisive of the age of the strata which contain them. I find among them no angiospermous plants, but several conifers and cycads. Of these I have been able to identify four, which have been found elsewhere, and are characteristic of the Lower Cretaceous rocks. They are,

1. *Zamites Montana*, Dawson, found in the Kootanie series of western Canada, and perhaps not different from *Zamites Articus*, Heer, from the Older Cretaceous (Kome) beds of Greenland.

2. *Podozamites latipennis*, Heer, found in the Kome beds.

3. *Sequoia Smittiana*, Heer, one of the most characteristic coniferous plants of the Kome and Kootanie strata.

4. *Sequoia fastigata* (?), Heer; specimen small, but corresponding closely with twigs of the species to which it has been referred, and which was first obtained from the Lower Cretaceous of Greenland.

These plants prove beyond question that the Great Falls coal basin is of the same age with those that have been described north of the boundary line by Dr. George M. Dawson, in what he has designated as the Kootanie series. Judging from the absence of dicotyledonous leaves, this formation, like that of Kome, Greenland, belongs to the lower half of the Cretaceous system, and is older than the Dakota group.

The Great Falls coal basin was at one time a fresh-water lake as we learn from its Unios and land plants, and from the absence of all marine fossils. This is also indicated by what we know of the condition of the North American continent when this coal was formed. The great subsidence which occurred in the middle of the Cretaceous age and resulted in the spread of the Dakota sandstones, had not yet taken place, and the sea was hundreds of miles away. Dr. George M. Dawson has suggested that the Kootanie series was synchronous with the coal-bearing rocks of Queen Charlotte's Island, which are much older than those of Vancouvers Island, and are supposed by the Canadian geologist to be of the age of the Gault. Within the United States the Shasta group of California and the Potomac group of Virginia, both of which are older than the Dakota, may be of about the same age, but

the Shasta group has yielded no plants, and the abundant flora of the Potomac series is now under examination by Prof. Fontaine, and until his monograph shall be finished we lack the means of satisfactory comparison.

The Comanche group of Texas has been shown by Dr. White to represent the very lowest members of the Cretaceous system in the Old World. This is, however, a marine deposit abounding in the remains of animal life, but without plants, so that here again comparisons except of the most general sort are impossible.

The area of the Great Falls coal field has not yet been determined, as only the southern margin is known to be exposed. That part of the series which contains coal outcrops along a belt extending from east to west, thirty or forty miles. The strata here dip towards the north, the coal passing under the barren sandstones and shales which form the Falls of the Missouri, and all the bedded rocks are concealed by drift as far as observation has extended northward of the river. Coal is reported at several places south of the boundary, and the geology of the country north of it has been studied by Dr. George M. Dawson. He reports several coal basins of economic importance, among others that of Kicking Horse Pass on the Canadian Pacific Railway of the same age as the coal of Great Falls, but over a considerable area, like the Cretaceous coal of Crested Buttes, Colorado, and that of Queen Charlotte's Island by local volcanic action converted into excellent anthracite.

Kersantite.—A New Building Stone.

My attention has recently been called to a crystalline rock found near Croton Landing, on the Hudson, which has some local reputation as a building stone, and which, from its peculiar qualities and its novelty among American rocks, seems to me to deserve a brief notice.

This rock has the general aspect of a granite, and has been classed as such by those who have seen or used it. It is true that it possesses all the good qualities of a granite for purposes of construction and these in an unusual degree, so that economically it may be considered as a granite, but mineralogically it is quite distinct from all granites, and is in fact a representative of a somewhat famous

rock of Brittany which has recently been the object of careful study, and is known as Kersanton or Kersantite. This has been largely used in the country where it occurs for architectural construction and decoration, for which it is admirably adapted by the facility with which it is worked, its great strength and durability. It is an ancient igneous rock coming into the category of Plutonic rocks, inasmuch as all the erupted portions of it, if any such existed, have been long since removed by erosion, and the masses we now observe have consolidated at considerable depths below the surface.

The essential constituents of Kersantite are a plagioclase feldspar, generally oligoclase, and biotite. With these sometimes occur quartz, hornblende or pyroxene, giving rise to varieties which are named from these minerals. The Kersantite of Croton Landing has been sliced and examined under the microscope by my assistant, Mr. Merrill, and he finds it to consist of oligoclase and biotite, with some apatite and perhaps a little hornblende. Doubtless other minerals are contained in it, but not in sufficient quantity to affect its classification or uses.

Having occasion recently to visit the quarries at Croton Landing, I found the Kersantite outcropping on the summit of the divide between the valleys of the Croton and the Hudson, perhaps two miles north of their junction. All the surrounding country is underlain by laminated micaceous gneiss of Archean age, of which the layers stand nearly vertical. At one point on the land of Mr. W. G. Winslow, the gneiss is pierced by a dome or neck of Kersantite, of which an area of two or three acres has been exposed by the great erosion this region has suffered. All the hills are rounded over by glacial action, and large surfaces of the underlying rock are denuded of vegetation and soil, showing all the characteristics of glacial erosion.

The Kersantite projects somewhat above the gneiss, having been left in relief from its greater resistance; its exposed surfaces are comparatively smooth and apparently as firm and sound as when left bare by the retreat of the glaciers, thousands of years ago. The rock varies somewhat in coarseness of crystallization, some of it being fine grained and resembling the Westerly granite; other portions are coarser and are composed of masses of white feldspar and brown biotite, a quarter of an inch or more in diameter. Some joints traverse the mass of Kersantite, but it is without distinct bedding, and where it has been quarried, seems to have been worked

with equal facility in every direction. It is remarkably homogeneous and blocks of any desired size could be taken out which would be essentially alike throughout.

The excellence of this material for purposes of construction consists, as I have said, in its strength, durability, and the facility with which it can be worked. Specimens tested by General Gilmore showed the extraordinary resistance to a crushing force of 20,250 pounds to the square inch; its specific weight is 2.852; the weight per cubic foot 178¼ pounds; its ratio of absorption of moisture $\frac{1}{120}$. With all this strength and durability which the exposed ledges demonstrate, it is much more easily worked than any ordinary granite, because it contains no quartz. It might be supposed that the mica in it would be an element of weakness, but it is as hard as the feldspar, and neither shows any signs of decomposition on the weathered surfaces. Indeed, on surfaces which have been exposed for thousands of years, the crystals of mica are slightly in relief, showing that this element weathers a little better than the feldspar. From its density and homogeneity, this variety of Kersantite takes a fine polish, which it will long retain unimpaired. When polished it has the aspect of a dark gray granite; while chiselled surfaces are nearly white. In strength and toughness it approaches the greenstones (diorite and diabase), but the replacement of hornblende and pyroxene by biotite makes it much easier to work.

Geologically, this rock is a very ancient eruptive, which burst through the Archean sediments, probably before the Silurian age. It seems to come into the same category with the Cortlandt series of rock found at Kruger's, Stony Point, etc., recently studied geologically by Prof. Dana, and lithologically by Prof. Williams, of Baltimore.

Grahamite in Colorado.

Some years since I obtained from western Colorado specimens of a coal-like hydrocarbon which closely resembled Grahamite, and which, upon chemical examination by Prof. Henry Wurtz, proved to be practically identical with it in composition. Recently I have received from Mr. J. J. Hagerman, of Colorado Springs, a mass of similar material from another locality south and west of Leadville. He writes me that it occurs in fissures, some of which are several

feet in width, and that it apparently exists in large quantity. If so, it is likely to be a matter of considerable economic importance, as the asphaltic coals, of which this is one, are in great demand in all our cities, where they are used for enriching gas.

This group of hydrocarbons, to which Albertite and Chapapote belong, is undoubtedly a derivative from petroleum, which, flowing into fissures, has, in process of time, perhaps ages, become by evaporation and oxidation, first asphalt and then asphaltic coal. It has been urged against this theory by Wurtz and Peckham that masses of the wall-rock are sometimes found inclosed in the Grahamite or Albertite far above the bottom of the fissure. I fail to see the force of the argument, however, inasmuch as the accumulation of the solid hydrocarbon must have been from below upward, and was maintained by the influx and evaporation of petroleum. There must have been always a mass below that would support blocks of stone falling in from the sides of the fissure, and the substance passed through stages of maltha and asphalt in which a stone would sink, but finally come to rest perfectly imbedded in the plastic mass.

The origin of Grahamite is, however, no longer a matter of debate, since it has been produced artificially by Mr. W. P. Jenney, who caused it to precipitate from petroleum by the long continued forcing of air through it (*American Chemist*, vol. v., p. 359).

The relations and genesis of Grahamite and its associated asphaltic coals are given in my paper on the Carbon Minerals, published in the *Annals of the New York Academy of Sciences*, vol. ii., p. 267, from which I extract the following table, where these may be seen at a glance.

PLANT TISSUE.

Residual Products.	Evolved Products.
Peat. Lignite. Bituminous coal. Semi-bituminous coal. Anthracite. Graphitic anthracite. Graphite. Ash.	Carbonic acid. Carbonic oxide. Carburetted hydrogen, etc. Water. Petroleum: Maltha. Asphalt, Ozokerite, etc. Asphaltic coal. Asphaltic anthracite. Asphaltic graphite.

The Origin of Graphite.

In the article on Graphite in Johnson's *Universal Cyclopædia*, and in a paper on "The Origin and Relations of the Carbon Minerals," published in the *Annals of the New York Academy of Sciences*, vol. ii., No. 9, 1882, I have advanced the view that graphite is the last term in the series of residual products formed in the spontaneous distillation of organic tissues, both vegetable and animal. I have there cited coal transformed into graphite at Newport, Rhode Island, and Craigman, Scotland, and specks and plates of graphite in the marbles of Amity and Ticonderoga, New York, as illustrations of two modes of occurrence, and apparently two sources of this substance.

A new example of the derivation of graphite from coal has recently been brought to my knowledge, which seems worthy to be put on record.

Mr. J. H. Banks, E.M., has lately returned from a visit to the coal field of Sonora, Mexico, bringing with him an interesting and instructive series of notes and specimens, which he has kindly submitted to me.

This coal field has long been known, and to a limited extent worked, but has been as yet only imperfectly explored. It occupies an area of many hundreds, perhaps some thousands of square miles, in central and eastern Sonora. The best known outcrops of the coal are those at Los Bronces, on the Yaki River, visited by Mr. A. Remond, in 1863. Specimens of the coal and a large series of fossil plants collected by him were sent to me for examination; they proved the age of the deposit to be about that of the Richmond coal basin, that is Upper Triassic.

On the Yaki river the coal seems to be all anthracite of good quality, containing about as much volatile matter as the Lackawanna coal of Pennsylvania. At some distance east of the Yaki river the coal is said to be bituminous and similar to that of Richmond, Va. The locality visited by Mr. Banks is San Marcial, 40 or 50 miles southwest of Los Bronces, and about the same distance from the railroad which leads from Hermosillo to Guymas.

All the western portion of this coal field seems to be much broken up by trap dikes which have everywhere metamorphosed the coal and converted it into anthracite. At the locality examined by Mr. Banks the metamorphic action has been extreme, convert-

ing most of the coal into a brilliant but somewhat friable anthracite, containing three or four per cent. of volatile matter. At an outcrop of one of the beds, however, the coal was found converted into graphite which has a laminated structure, but is unctuous to the touch and marks paper like a "lead pencil."

The metamorphism here is much more complete than at Newport, furnishing the best example yet known to me of the conversion of a bed of coal into graphite.

THE SEPARATION OF NICKEL AND COBALT FROM IRON.

BY J. B. MACKINTOSH.

As all chemists know, the separation of these metals is, at best, a long and tiresome task. It is generally assumed that two or at most three precipitations of the iron as basic acetate, or as hydrate by ammonia are sufficient to effect a perfect separation, thus obtaining all the nickel and cobalt in the filtrates. I have found, however, in cases where there is a comparatively large amount of these metals present, as in most meteoric irons, that it is sometimes necessary to repeat the precipitation five or six times or even oftener before the filtrates cease to react for nickel and cobalt. In the analysis of one meteoric iron I noticed the very interesting fact that after all the nickel had been removed, cobalt still remained with the iron, although the amount of cobalt in the sample was not more than one-tenth that of the nickel. At the time when this was noticed the color of the filtrate on concentration was pink, having previously been green; if I remember correctly this took place at about the sixth time of precipitation.

The probable reason for the difficulty seems to be, that the nickel and cobalt become partially peroxidized, and possibly in the case of cobalt that some of the ammonio-cobalt bases are formed, which are either rather insoluble or are decomposed, with formation of peroxide, upon boiling.

In order to decrease the time and the number of operations necessary, I tried the old method of precipitation of all three metals from the boiling solution with ammonium sulphide, with subsequent treatment with hydrochloric acid. I thus obtain two portions, the precipitate containing nearly all the cobalt and nickel

with very little iron, and the solution containing nearly all the iron with very little nickel and cobalt; both these portions are then treated separately in the usual way by precipitation of the iron as basic acetate, and a perfect separation may be much more readily obtained, than if the solution had been treated directly without this preliminary concentration.

I tested this method on two meteoric irons which I have recently analyzed,* and determined the amounts of combined nickel and cobalt found in the two portions after one precipitation as sulphides and also after three such precipitations. It is to be noted that these operations take very little time, as the precipitated sulphides of nickel and cobalt are easily filtered and washed, and also that the bulk of solutions treated is very small, so that the time occupied by these three precipitations, will hardly exceed that occupied by one basic acetate precipitation, and certainly will not when the time necessary for the concentration of the filtrate is taken into consideration. The results obtained are as follows:

PRECIPITATION OF THE BOILING SOLUTION WITH AMMONIUM SULPHIDE AND SUBSEQUENT SOLUTION IN DILUTE HYDROCHLORIC ACID.

	Total Ni + Co present.	Fe present.	Per cent. Ni + Co in precipitate	—in filtrate.
One precipitation,	0.0956	1.0266	92.08 per cent.	7.92 per cent.
Three precipitations,	0.1248	0.6021	96.32 " "	3.68 " "

In the first case the nickel and cobalt amount to 8.52 per cent. of the total weight of metals, and in the second case to 17.17 per cent.

LEHIGH UNIVERSITY, South Bethlehem, Pa.

CONCENTRATION OF GOLD AND SILVER ORES ON THE PACIFIC COAST.†

BY J. M. ADAMS, E.M.

CONCENTRATION of ores is simply the separation of the heavy from the light, and is performed sometimes on dry ore, but generally water is used, especially in California, where it is practiced principally on the ores of gold and silver, which are either native,

* American Journal of Science, March, 1887, pp. 225, 232.

† Published in part in the California State Mineralogist's Report for 1886.

or associated with, or part of, various metalliferous minerals; the gold and silver, as well as the minerals, being much heavier than the gangue or vein matter in which they occur.

They are freed to a large extent from the gangue by crushing or pulverizing to a proper degree of fineness, and according as the concentrating work is more or less perfect, the separation is made of the heavy or valuable part of the ore from the gangue. Occasionally the finest part of the crushed ore is very rich, and is worth saving by itself.

In dry concentration this is the dust, and is separated and saved if of sufficient value.

In wet concentration this light portion is the slime, and if rich enough the pulp is passed through a pointed box (see cut and description below). The slimes pass off from the top, to be settled and saved, the balance discharging from the bottom to the concentrator, for separation of the mineral.

In some cases it is preferable to put the pointed box below the concentrator, and thus separate the rich slimes from the tailings. As a rule, however, most of the money in the slimes exists as finely divided sulphurets, which are caught and saved with the balance of the sulphurets by the best concentrators, so that there is only an occasional ore whose slimes need segregation and saving.

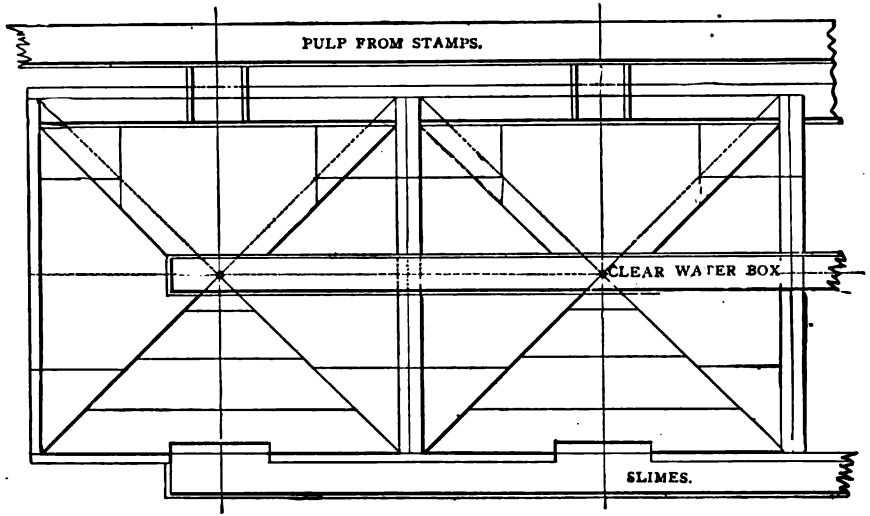
Several forms of pointed box are in use. Their dimensions vary according to the duty required. In some cases it is desired to settle all the pulp, including the slimes, when there is too much water present for subsequent concentration. In such event the pointed box should be about 6 feet deep, and 3 feet by 7 feet at the top, the longest sides sloping till they meet at the bottom.

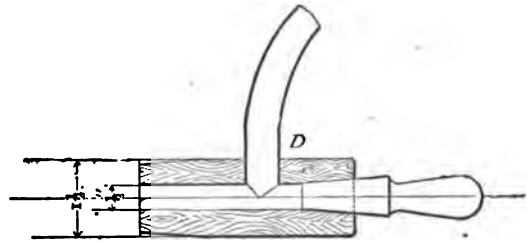
Such a box will settle and save about six tons of ore in twenty-four hours, discharging it automatically and continuously from the bottom by a siphon hose, with the proper amount of water for subsequent concentration.

This form is used when the tailings from pan amalgamation are to be concentrated, after leaving the settlers and agitators, for they contain a large excess of water, which must be gotten rid of, so that the tailings are of the proper consistency for concentration.

The accompanying cuts (Figs. 1 and 2) show a form of pointed box used in cases where the slimes are to be separated from the battery pulp and saved. Each box is 40 inches square at the top,

FIG. 1.

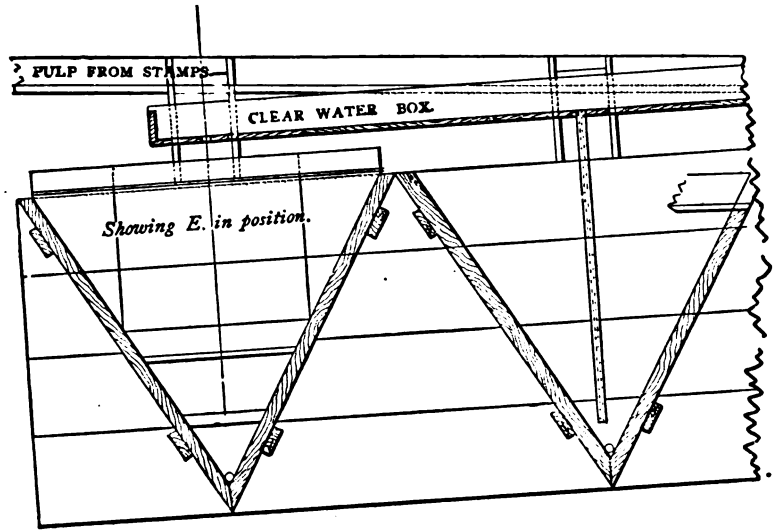


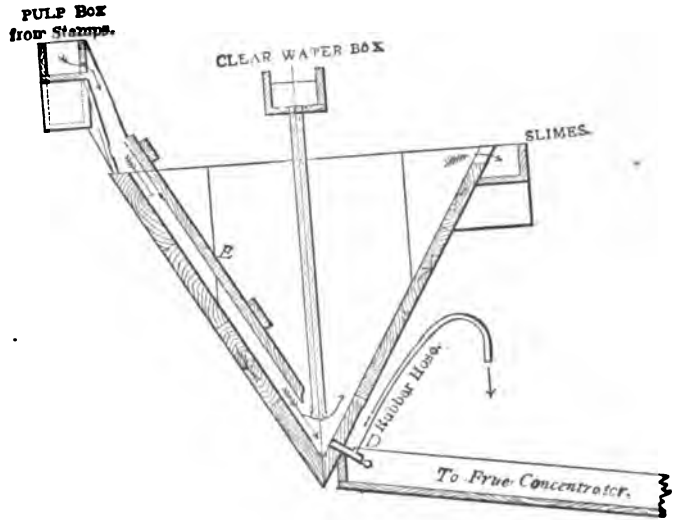


POINT BOX.

Scale, ½″ = 1′

FIG. 2.


PULP FROM STAMPS.
CLEAR WATER BOX.
Showing E. in position.


PULP Box from Stamps.
CLEAR WATER BOX
SLIMES.
E
Rubber Hose.
To Frue Concentrator.

and 40 inches deep, coming to a point at the bottom; and one box will handle from 6 to 10 tons of pulp in twenty-four hours, making a good separation.

The pulp from the battery, entering the box at the top, is confined by partition *E*, until it passes into the box proper, near its bottom. Clear water is conveyed from above through a ½-inch pipe, which delivers it into the box at the bottom. Care must be taken that this pipe is kept full, so that no air bubbles are carried through it, as they create agitation, and cause sand, etc., to pass off with the slimes.

The amount of clear water needed varies, so it is a good plan to have a cock in the pipe just below the clear water box, or else to partially close, with a wooden plug, the opening of the pipe in the clear water box. At *D* is a hollow plug, and to it is attached a piece of hose, which is used as a siphon, so that the pressure is lessened and too violent discharge of the pulp is prevented.

Without the siphon hose, ⅛-inch opening would not be too small, while with it ⅜-inch opening is about right, and the end of the hose is plugged accordingly. Inasmuch as foreign coarse material occasionally gets into the box (prevented as much as possible by a screen over the top), it is advisable to use in place of the hollow wooden plug shown, a 1½-inch iron tee with one end plugged, and with ¾ inch side outlet, attaching the siphon hose by nipple.

Thirty-five years ago, concentration in California consisted simply in saving the placer gold, and the appliances used were the rocker and sluice. Various grades were given to the sluice; its bottom was formed in various ways, some using plain riffle bars, some preferring blocks of wood sawed across the grain; others liked boards, full of round holes, undercurrent riffles, etc. Sometimes quicksilver was used to catch the gold; sometimes none was used.

When gold was discovered in quartz in California, and reduction works for the same were to be constructed, Californians knew nothing of the required means, and had to adopt the old square wooden stem Cornish stamp, the arrastra, etc., but with the ingenuity, native to Americans, improvements were rapidly made, and to-day American (United States) machinery for mining and reduction of gold and silver ores is the best in the world.

The old-fashioned stamp was replaced by the round iron stemmed

stamp, revolving as it is lifted by the cam, and with cams, tappets, shoes, and dies of cast steel, the wear has been reduced to a minimum. The present standard American stamp mill is a very different crushing appliance from the clumsy stamps first used by us.

Most of the quartz veins worked in early days were either much decomposed on the surface, or were clean quartz containing the bright yellow gold. As depth, however, was attained, the decomposed ores changed, and sulphurets of iron and copper, with galena, blende, and other minerals, were found. The ore did not yield as much of its gold as the surface ore; there was some gold in the tailings, and further examinations showed that a large part of the loss was in the sulphurets; hence we began to realize that there was money in the sulphurets, and two problems arose:

First. How to save the sulphurets.

Second. How to realize the money contained in them after they were saved.

In regard to the second problem it was soon known, that if rich enough, they could be sold to parties who would send them to smelting works in Europe, while in some cases quite a proportion of the gold could be saved by thorough amalgamation in pans or barrels, and about 1867 it was proved that a high percentage of the gold could be profitably extracted from the sulphurets by roasting and chlorination.

As regards the first problem, "How to save these gold-bearing sulphurets," the necessity of concentration became apparent, as the only economical method was by taking advantage of their greater weight and separating them accordingly.

Labor being very high, automatic concentrators became a desideratum, stimulating the inventive faculties of many who were engaged in mining. Various machines were devised and tested; most of them proved to be of little value, and the appliances in general use for saving sulphurets in California in 1875 were few in number, being as follows:

The sluice with blankets or burlaps.

The sluice with riffles and the buddle.

The raising gate.

The Hendy concentrator.

The grade of the sluice, using blankets or burlaps, was generally about ½ inch to the foot. A double set was used; the blankets or burlaps in one set being taken up and washed, while the other

set was in use. By very frequent washings the sulphurets were obtained fairly clean, but this took so much labor that they were seldom washed; the ordinary product contained much sand, and the sulphurets contained were coarse, the finer sulphurets passing off, although nearly equal in quantity, and frequently much richer than the coarse sulphurets.

The grade of the sluice with riffles was about ¾ inch to the foot, and the sluice was generally of the following type: Two sets are used; each riffle is formed by a ½-inch strip of wood, fitting across the sluice, and about 10 feet from the next riffle. At stated periods, according to the amount to be collected (varying in different ores), another strip is placed on top of the previous one, and this is continued until the sluice is nearly full at each riffle, when the tailings from the mill are turned into the other set of sluices for similar treatment, and the material accumulated in the first set of sluices is collected, and further concentrated in a buddle, of which there are several styles.

The accompanying cuts, Figs. 3 and 4, show a common form of buddle, and may be described briefly, as follows: It is circular, with concave bottom, and the discharge for the tailings is in the centre, where there is a hollow iron cylinder, shown in the cut, with its top or rim even with the bottom of the buddle. In this position everything will flow out of the buddle, but this ring or cylinder is attached to an upright spindle, and by the gear at the top is gradually raised, retaining in the buddle the sulphurets as they accumulate, and constantly raising the discharge of the tailings; the arms, also, from which the brushes hang, are gradually raised at the same time by the mechanism.

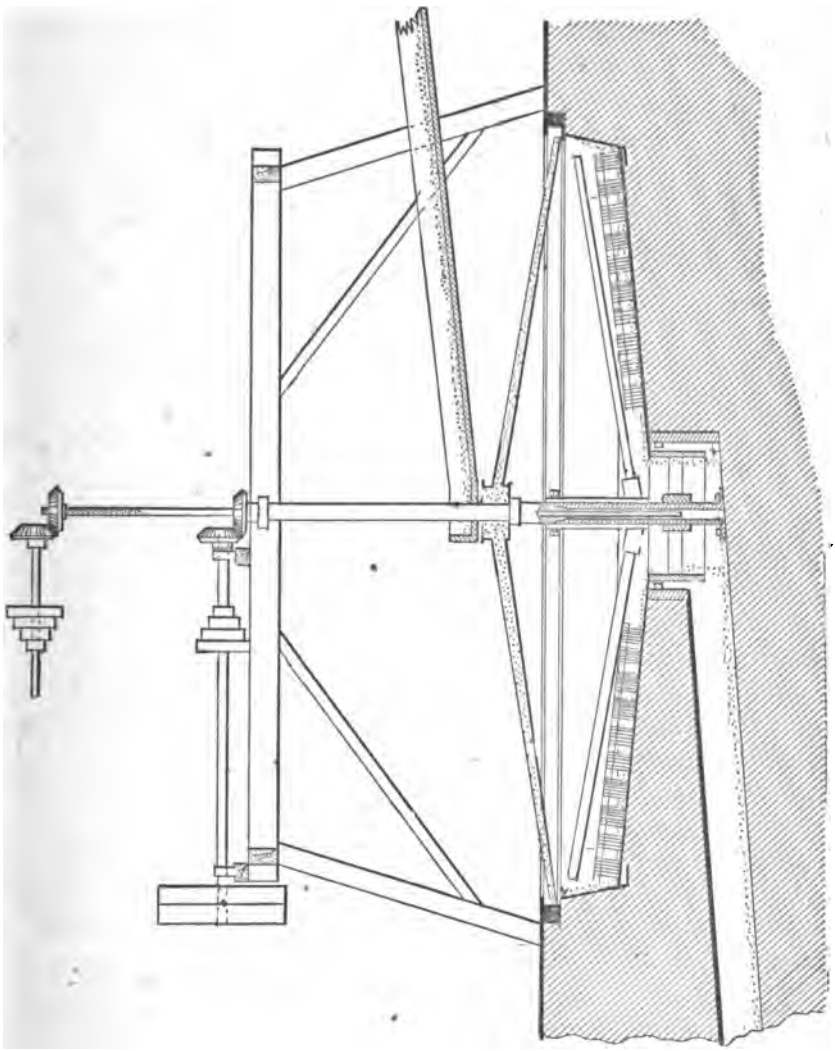
The material to be buddled is delivered from above the centre through six pipes at the periphery of the buddle. Very little water is used, and there is no agitation except that made by the brushes, which are constantly moving around the circle, resting on the pulp, and being dragged around by the arms.

By means of the step pulleys above, the gradual raising of the discharge cylinder and of the brushes is regulated as required for the material operated on. When the buddle is full of sulphurets, it is stopped and cleaned out.

This system of sluice with riffle and buddle does very fair work if carefully attended to, but requires a large amount of labor, and does not save the *finest* sulphurets.

The raising gate may perhaps be best described as the sluice with riffles, improved by having the riffle raised gradually by

FIG. 3.

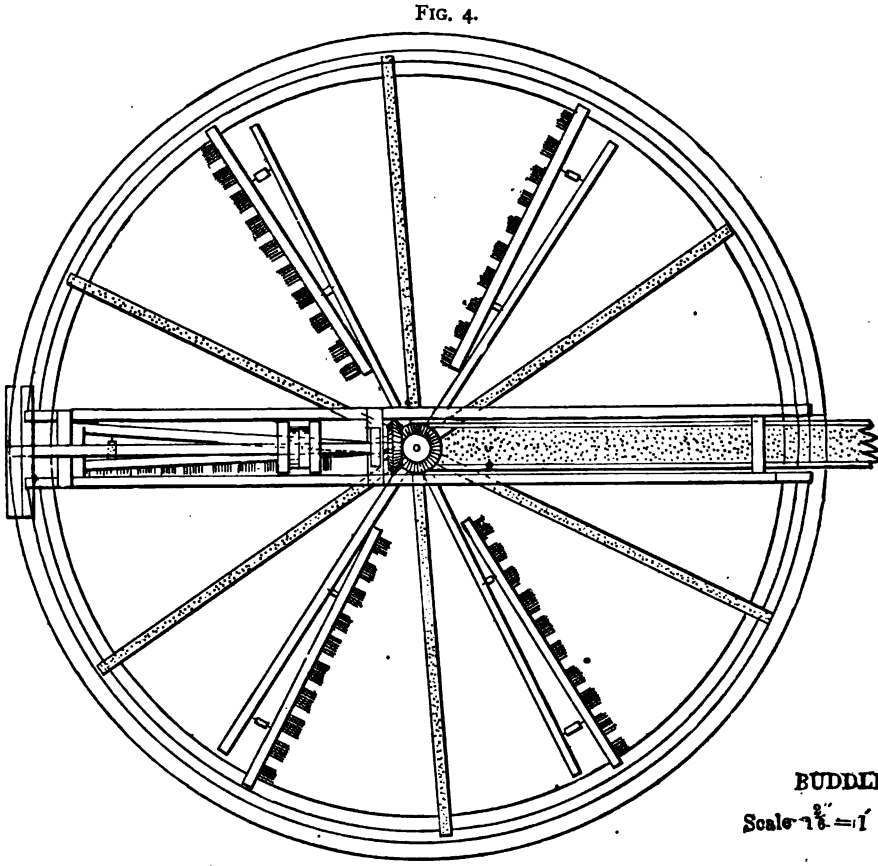


machinery. Fig. 5 shows the raising gate *down or open;* by the gear above it is gradually raised, the speed being changed at will by the step pulley.

It saves some labor, but its work is about the same as the sluice with riffles, described above.

The Hendy concentrator was used very extensively for several years. It is circular, and of iron; the bottom is slightly convex, and at its periphery is a circular or annular trough, deeper than the main bottom. By the crank shaft it is given a short, quick,

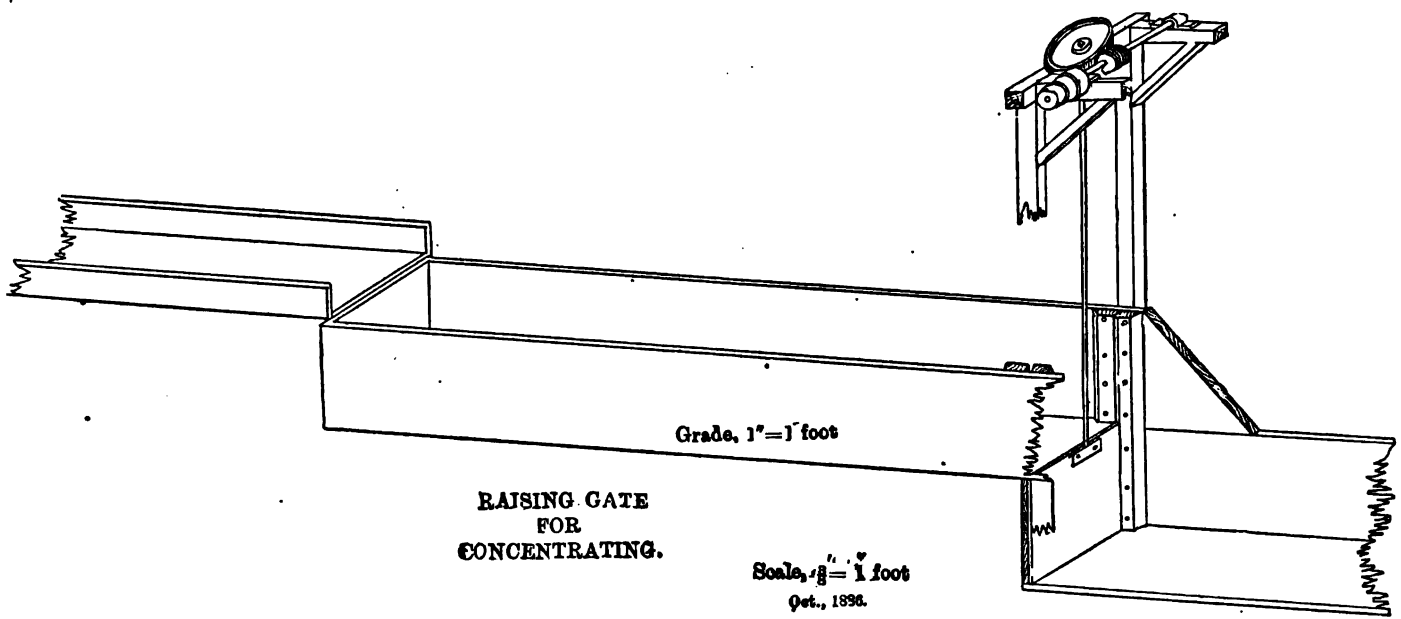
FIG. 4.



vibrating motion horizontally, turning on its centre as a pivot. The pulp is delivered into the bowl above the centre, and is conveyed by two arms or pieces of pipe, and delivered on the concentrator at its periphery.

A depth of about 3 inches of material is kept in the concentrator; the heaviest settling to the bottom, and being moved grad-

FIG. 5.



RAISING GATE
FOR
CONCENTRATING.

Scale, $\frac{1}{8}$" = 1 foot

Oct., 1896.

ually by centrifugal force towards the outside of the pan, where it collects in the annular trough, and discharges from a spout. The concentrations, still containing much sand, are passed through a third machine, and reasonably clean sulphurets obtained. The tailings pass off at the centre of the machine, through the bottom.

At the Keystone Mill of forty stamps the pulp is passed through these concentrators, and their tailings pass over sluices with riffles.

In 1875 the writer, with his partner, commenced the arduous task of convincing the mining men of the coast that there was a heavy loss passing away from all the concentrating appliances in use, and that even a perfect concentrator needed proper conditions and proper care to secure its most efficient work. In most cases it was difficult to convince parties that their loss was really so great, and frequently we would be told that if a concentrator was good for anything, it should run itself and need no attention whatever.

The concentrator advocated by the writer as embodying the most correct principle in a good mechanical appliance (subsequently improved and perfected), was the Frue vanner, or ore concentrator; and after three years' constant work, and an expenditure of $30,000, success was attained, and the mining public were largely convinced of the importance of proper concentration of the gold and silver ores of the Pacific coast.

The word "silver" is used because many of the sulphurets contain a large proportion of silver as well as gold. In the vicinity of Nevada City the production of sulphurets was more than doubled by using the vanners, and similar success attended their introduction and use elsewhere. Its success stimulated others to invent concentrators, so that many new concentrators have been brought before the public, many of them possessing merit, and almost all of them claiming superiority over the vanner.

Nevertheless, the sales of the vanner increase every year, and up to date amount to nearly $1,000,000.

The attention of the public is being drawn more and more every year to the importance and benefit of concentration, and even the low-grade silver and gold ores of the Comstock vein (Virginia City, Nevada) are being successfully and economically concentrated. These ores yielded no profit under the old method of amalgamation.

In former times the necessity of sizing even finely crushed ores

was strongly insisted on to properly prepare the ore for concentration, but sizing is rarely found advisable with the concentrators now in use.

In some of the mining districts of this State the ore is very heavy with sulphurets, containing 20 per cent. and over. Much of this can be separated by coarse crushing with rolls, etc., and jigging, and this method of treatment is advisable, as there is thus avoided a heavy loss of sulphurets in slime, which would occur if the original ore was finely crushed at first. The tailings from the jigs will still contain much sulphurets, locked up in the gangue, and should be finely crushed and passed over the vanner or some other concentrator.

Occasionally an ore is found in which the silver exists partly as chloride and partly as refractory sulphurets. Formerly such an ore was crushed dry, roasted, chloridized, and amalgamated, but even $30 ore would yield scarcely any profit, and the reduction works were very expensive.

For several years the writer contended that the proper method of treating such ore was by concentration first, and amalgamation without roasting of the tailings from the concentrators. In this manner the expensive dry crushing is replaced by wet crushing, which also doubles the capacity of the mill. The refractory part of the ore is saved by itself in such small compass that it can be either sold or shipped to smelters, or treated at the mill with small expense. The tailings from the concentrators do not need roasting, so that this great expense is saved, as well as the cost of the furnaces.

In some localities, ore worth only $6 a ton, can be made to pay by this method, while $30 ore would not pay by the old method of dry crushing, chloridizing, etc.

It is very important that the concentration is made before the amalgamation, for several reasons. The tailings from the concentrator contain no base mineral to trouble amalgamation or cause loss of quicksilver, and the Boss continuous process of pan amalgamation can be used with advantage and economy. If amalgamation be used before concentration, the sulphurets are ground, and a large part is thereby made so fine that it cannot be saved on any concentrator; too much water, also, is with the tailings, and there is an uneven discharge from the settlers and agitators.

After advocating this method for several years, the writer at last

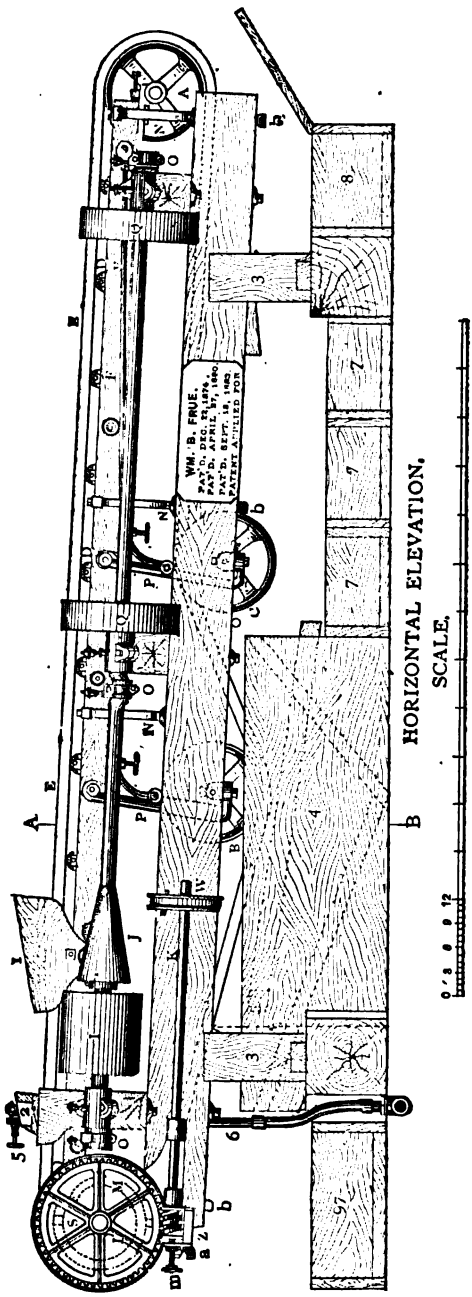

WM. B. FRUE.
PAT'D. DEC. 21, 1875.
PAT'D. APRIL 17, 1880.
PAT'D. SEPT. 18, 1883.
PATENT APPLIED FOR
HORIZONTAL ELEVATION.
SCALE.
0 3 6 9 12

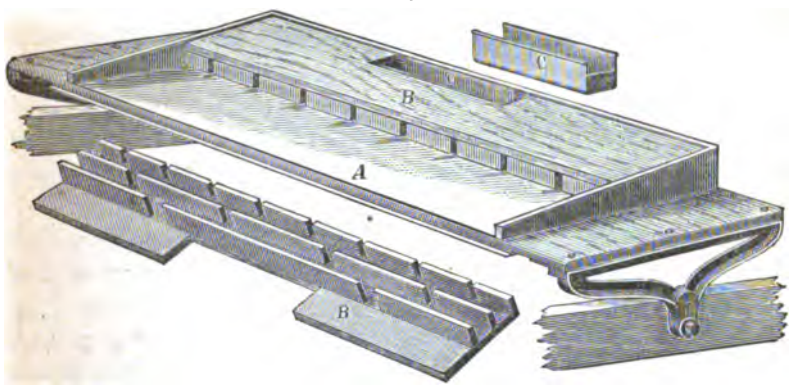
FIG. 6.

succeeded in having it adopted five years ago by Mr. Randolph, acting for Mr. Alexander R. Shepherd, in the mines of Batopilas (Chihuahua, Mexico), and it is in successful operation there to-day. It is now used also at several mines in the United States.

The Frue vanner consists of an endless travelling rubber belt, with raised sides, moving slowly up hill, forming an inclined table (about ¼ inch to the foot being the grade, subject to change according to the ore), and having a short lateral motion of 1 inch, given by a crank shaft running from 180 to 200 revolutions a minute.

It can be further understood by the cut of the working drawing, which shows most of the improvements, except the present form of the ore spreader, which is as per cut below, and was devised,

FIG. 7.



so that for gold ores, a silver-plated copper plate could be placed over the entire surface of the spreader, the top board *B*, with blocks attached, being put on the plate; also the copper well *C*, in which is caught quicksilver which may escape from the main plate above; when the plate is to be cleaned, the top board and blocks are removed; this is only done occasionally.

The ore with water is delivered on the belt by means of the spreader No. 1, in working drawing, which shakes with the table, and distributes the pulp uniformly across the belt. A small amount of clean water is distributed by No. 2, which is a wooden trough in which is a perforated pipe. A depth of ⅜ to ½ inch of sand and water is constantly kept on the table. The main shaft, *H*, should be given the proper speed for each kind of ore, and once

established, it should be kept uniform; this speed will be between 180 and 200 revolutions of the crank shaft per minute, with 1 inch throw.

The up-hill travel or progressive motion varies from 3 feet to 12 feet a minute, according to the ore, and the grade or inclination of the *table* is from 3 inches to 6 inches in 12 feet, varying with the ore. The inclination can be changed at will, by wedges at the foot of the machine. The motion, the water used, the grade, and the up-hill travel should be regulated for every ore individually, but once established no further trouble will be experienced in the manipulation.

The main body of the belt suffers hardly any wear, as it merely moves its own weight slowly around the freely revolving rollers.

For one machine, ½ inch of water (miner's measure), or 6⅛ gallons a minute, including the water used in crushing, is as large an amount as is ever needed on any material, while on some ores 3 gallons will answer; and by returning the water from the settled tailings ½ gallon will keep up the loss.

The boiler for a 5-stamp mill with 2 concentrators consumes 1 gallon a minute; hence, where water is very scarce, 2 gallons a minute can supply 5 stamps, 2 Frue vanners, and the boiler.

As regards the capacity of the Frue vanner, about 6 tons per twenty-four hours passing a 40-mesh screen is as much as it is advisable to treat. If the battery of 5 stamps does its duty, the quantity crushed is largely in excess of 6 tons. For this reason, the best practice is to put 2 Frue vanners to 5 stamps, if the stamps are heavy and the sulphurets high grade and difficult to save; and in such event the pulp is divided, one-half passing on each. The machines are generally placed in a double row, on the same level, head to head.

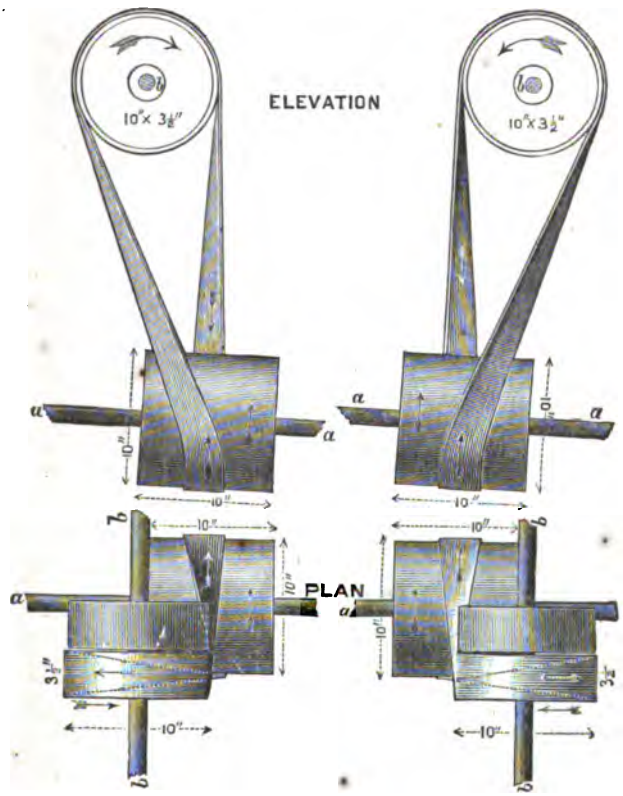
In many cases 3 vanners to 10 stamps will yield entirely satisfactory work, and where the gangue is light, or the stamps not heavy, 1 vanner treats all the ore crushed with 5 stamps, and does perfect work, *e.g.*, in the Empire mill of 80 stamps, at Plymouth, in Amador County, 16 Frues are concentrating all the ore crushed by the 80 stamps, and the tailings assay merely a trace. No sizing of the ore is needed; the pulp passes directly from the stamps on the copper plates (if used), and thence on the vanners.

In running the machine the point of greatest importance is regularity; regularity in speed; regularity in the delivery of pulp

on the belt, and regularity in the supply of clear water. The necessity of this is obvious to any one who thinks of the work to be done by an automatic machine.

With hand labor the judgment of man regulates the means employed in conformity with varying conditions; but in a machine, the object of which is to supersede hand labor, it becomes obvious

FIG. 8.



Countershaft for Frue Concentrator.

that having once adjusted the movements to effect a certain object under certain conditions, the desired result can only be attained by the maintenance of the necessary conditions.

In this concentrator, supposing the inclination of the belt to be fixed for a certain class of material, the regulation of the work to be accomplished is effected by three things, viz., the speed with which the belt revolves, the rapidity of the side shake, and the

supply of clear water at the head. Having adjusted these three conditions to a given feed delivered on the belt, that feed should remain constant, and the result, both in the richness of mineral collected and in the poverty of the tailings, will be continuously maintained.

The countershaft to drive the Frue concentrators is placed parallel with the cam shaft and main line shaft of the mill, and is, therefore, at right angles to the crank shaft and pulley of the vanner. This necessitates the use of a quarter-twist belt, and the proper placing of this countershaft is very important, for with it properly set, the quarter-twist belt runs as well, as true, and with as little wear as if it were a straight belt; while if not properly set, it will run off the pulley.

As this is not generally understood, even by good mechanics, the accompanying cut (Fig. 8) is given to illustrate the placing of this countershaft: *a a* is the crank shaft of the concentrator; *b b* is the countershaft; on *b b* are one tight and one loose pulley; the belt is shown on the tight pulley. The crank shaft is not horizontal. The rule is as follows: "In placing the countershaft and its pulley, the pulley should be set so that the side from which the belt leaves it is in line with the square of the crank shaft of the concentrator at that point."

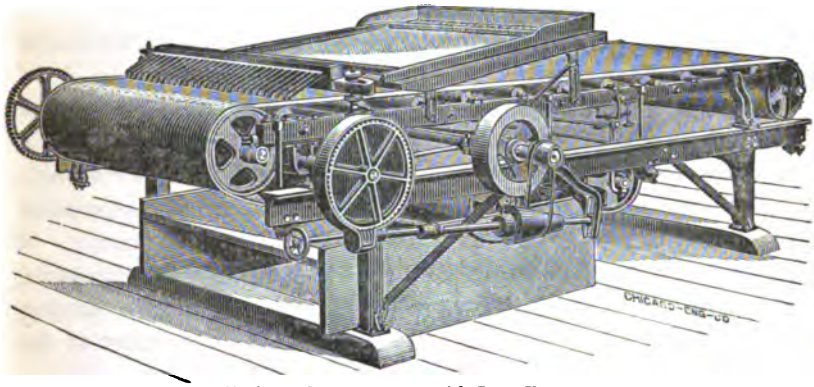
The Embrey concentrator is similar in most respects to the Frue vanner, differing chiefly in the direction of the shake, which is longitudinal. Not many of them have been put in use in California, as the Frue Company owns the Embrey patent, and believing the vanner to be the best machine, they have not pushed the Embrey.

Two forms of the Embrey machine are made, one compact in form, with crank shaft passing under the shaking frame, and supporting, by the latter, the whole weight of the belt and two underhanging rollers. This form is, in fact, identical with the vanner, except that the crank shaft is placed at right angles to the length of the belt, instead of parallel to same, and it is made with iron or wood frame, as preferred.

The second form, and the one most desirable for economy in running, is arranged with the driving shaft at the lower end of shafting frame, so that while running, all parts can be regulated, and any play taken up, and the shaking frame does not carry the hanging rollers, which are supported by the main frame, and carry

about one-half of the main belt. The shaking frame and mechanism is thus relieved of the weight of the two lower rollers, and nearly one-half of the weight of the heavy belt, an important point, considering the high speed necessary on the end shake machine.

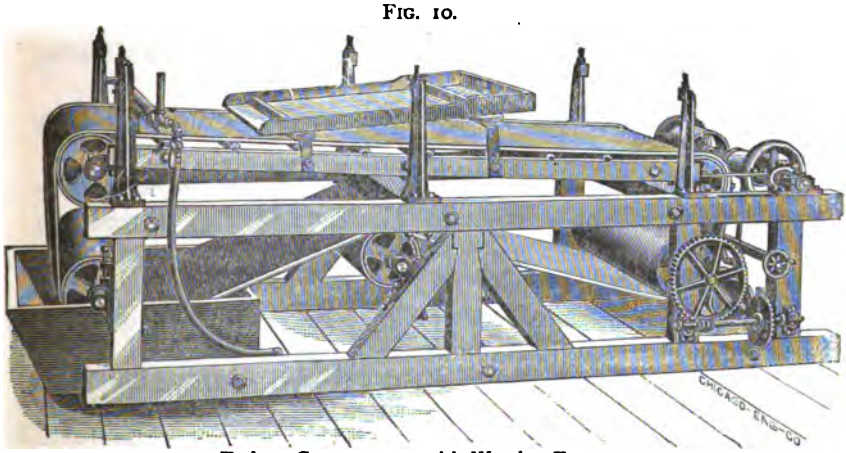
FIG. 9.



Embrey Concentrator, with Iron Frame.

The only advantage of the first form over the second is in saving a little floor space for the same length of working belt.

FIG. 10.



Embrey Concentrator, with Wooden Frame.

The advantages of the second form are in reduced power required, reduced wear and tear, and greater accessibility of working parts while in motion.

The accompanying cuts (Figs. 9 and 10) show the two forms of

the Embrey, as they were made some time ago. Since they were engraved several improvements have been made, but time did not permit later cuts to be made. A few of the improvements consist in mechanism for regulation of the progressive motion from in front of the machine; and the carrying or shaking frame is now supported from below, in the wooden frame machine, and not from above, as in the cut. Silvered copper plates on the ore distributor are used, when needed, to save amalgam.

If on the same belt both end and side shake mechanism be applied alternately, with the same conditions of feed and speed, it will be found that at a speed of 180 to 200 revolutions per minute, and the ordinary slight inclination of the belt, a perfect separation of clear mineral can be made on most ores with the vanner. If the end shake be substituted now, other conditions being the same, it will be found impossible to keep back the sand from passing over the mineral, even with excessive use of clean water at the head; and a separation can only be accomplished by increasing the speed to 235 or 240 revolutions, and increasing the speed naturally increases the wear and tear very materially.

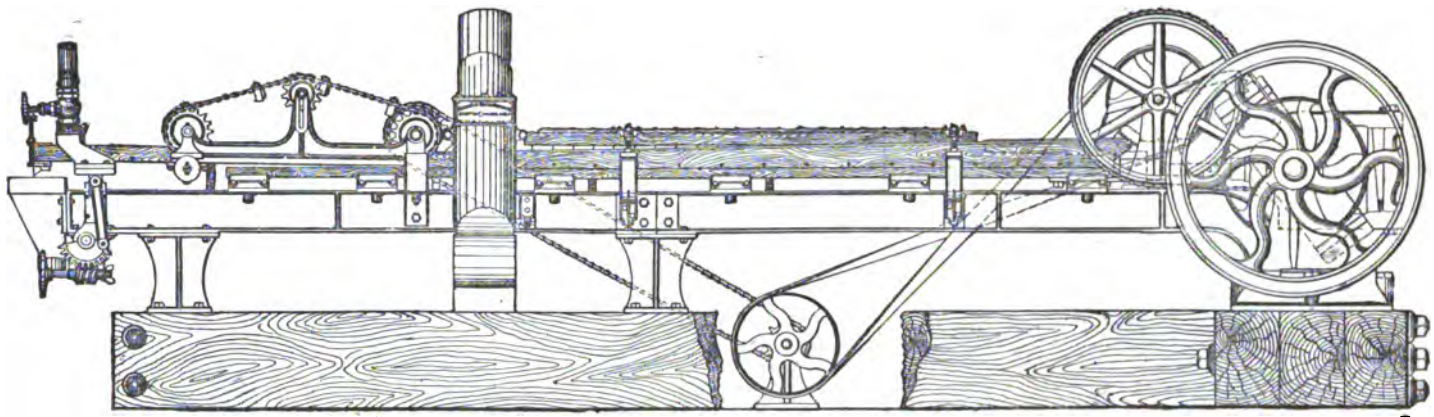
The Embrey is in use in several mills in Colorado, Montana, the Southern States, etc., and at the Anaconda Copper Mine in Montana, the wooden-frame Embrey is preferred to any other concentrator. One of its patented points is the use of the vibrating water distributor.

The Triumph concentrator is very much like the Embrey, which is the earlier machine.

It is a rubber belt, inclined, shaking longitudinally, and revolving slowly. Its crank shaft, like the Embrey, revolves from 235 to 240 times a minute, in order to make the separation of the mineral from the sand. Its main novelty is the use of a friction roller to regulate the forward motion of the belt, instead of a cone pulley, which is used in the vanner and Embrey machines. It has also an amalgam saver, consisting of an iron trough in which turns slowly a horizontal shaft with stirrers. Quicksilver is kept in this trough. The shaking table is supported on upright springs, and the main frame is of cast iron. It is a neat looking machine, and can do good work. Many machines have been sold. It is in use at the Empire Mill (Grass Valley), and is liked.

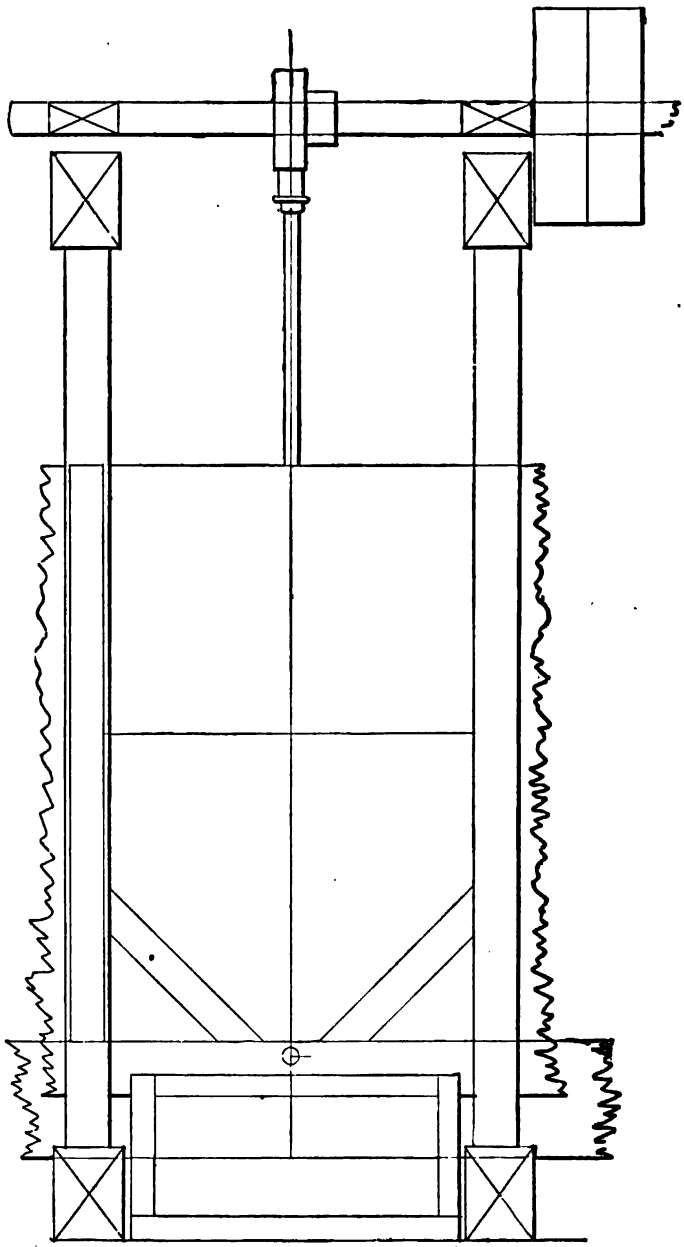
The Duncan ore concentrator, like the Hendy concentrator, is circular in form, and of iron. Its principle is an ingenious com-

FIG. 11.



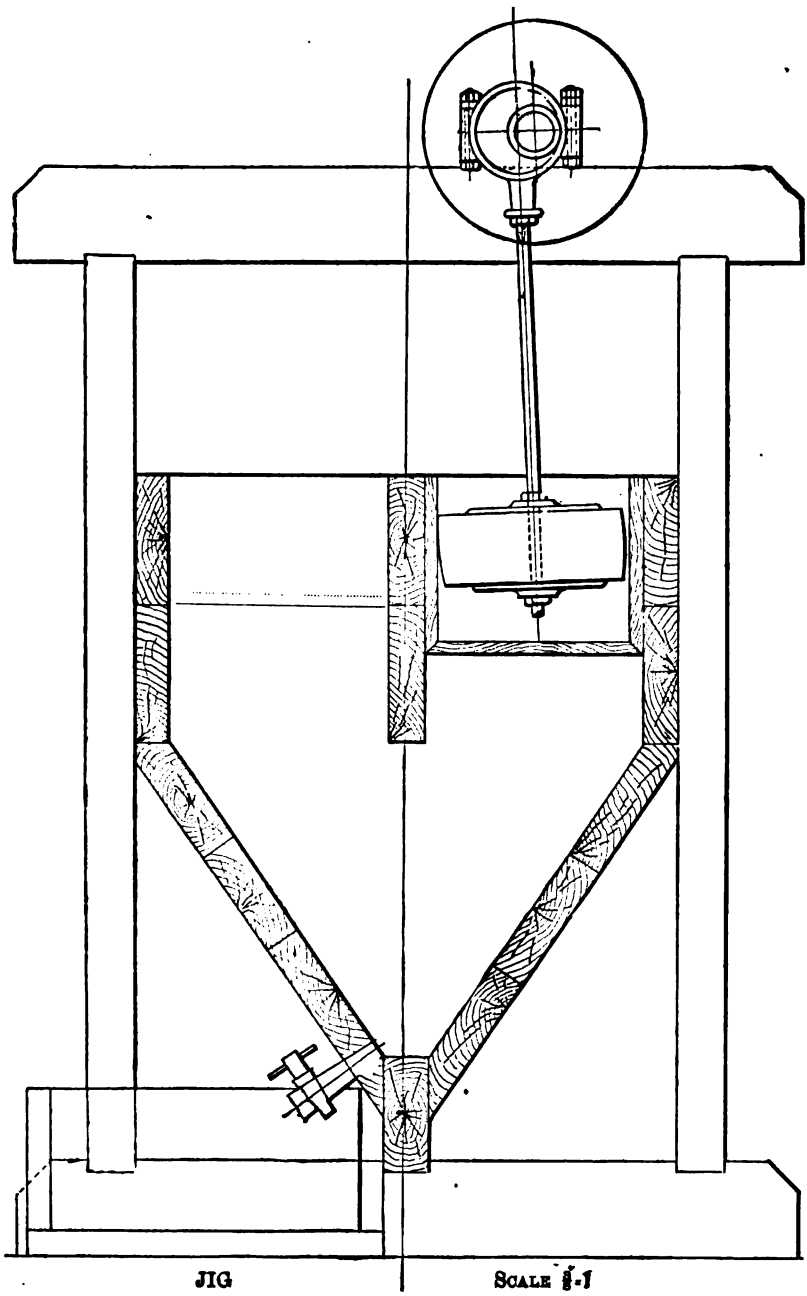
Golden Gate Concentrator.

FIG. 12.



JIG SCALE $\frac{3}{4}$-1

FIG. 13.



JIG SCALE 1-1

bination of movements, imitating the process of panning by hand. "The agitation resulting from this movement causes the mineral to settle to the bottom around the outside of the pan, where it is held by centrifugal force, until discharged through the gates, while the gangue is held in suspension, and gradually carried by the force of the current to the central discharge. The pan, by this centrifugal motion, making, say eight and a half revolutions per minute, causes the pulp to flow around over its surface to the extent of about three revolutions, or equal to a distance of some thirty feet before it is discharged, thereby giving the sulphurets or other mineral time to settle before the gangue passes off. The wrist-pin, on the balance-wheel, is made adjustable, so that the motion of the pan can be varied to adapt it to the requirements of different classes of ore."

The foregoing is the description given by the manufacturers and owners of the Duncan concentrator. It is well made, and many have been sold. Its weight is about 1750 pounds, and it requires to run it about one-half horse-power.

The Golden Gate concentrator is a modification of the Imlay, and is a shaking table with raised sides, having an end shake quicker in one direction than in the other, so given by means of differential gear. The pulp is delivered at one end of the table, and the table is covered with a depth of about 1 inch of pulp, which is kept loose and agitated by the shaking motion, assisted by many stirring pegs, which are attached to a top frame. The bed of the table is covered with rubber, and is horizontal for about three-quarters of its length; the remaining one-quarter has a slight inclination given it, and at its head a supply of clear water is delivered across the table. At the angle where the horizontal part of the bed and the inclined part meet, is a strip of copper or protecting plate about 4 inches wide, reaching across the table from side to side; underneath this plate is sufficient space for part of the pulp and mineral to pass through, and above the plate is the suction appliance and exhaust pipe, with vacuum, maintained by a small fan, for drawing off and discharging the tailings, which partly pass from the horizontal part of the table over the plate, and partly are washed down the inclined part; the concentrations and coarsest sand working up the incline and falling into the concentration box outside. It is an ingenious contrivance, by means of which the pulp is received at one end, the concentrations delivered automati-

cally at the other end, while the tailings are sucked up and discharged from near the middle.

The machine is very well made, and of large capacity; it is in successful operation at the Brunswick Mill, Carson River, Nevada, where six of them are handling the product of fifty-six stamps, crushing one hundred and sixty tons of ore a day, and is also in use in other places. It saves the heaviest and coarsest mineral, but has not been successful on all the ores tested. In the writer's opinion a shaking table cannot save finely divided mineral, because the mineral has to be shaken up after settling nearly three hundred times a minute, each time being carried ahead a little; each particle is settled only to be disturbed again, and when it reaches the incline, and has to be shaken up-hill against the water, it is impossible to prevent the fine sulphurets from being carried down with the tailings and sucked off with them; hence, the Golden Gate has been unsuccessful on ores in which the fine sulphurets are of much value.

There are possible problems in concentration in California requiring coarse crushing; this has already been discussed, and, consequently, the accompanying cut of one of the most approved styles of jigs should be of interest.

Dry concentration is not discussed in this article, because it is little used in California, and, in fact, is rarely adopted if water can be obtained in sufficient quantity for wet concentration, because the latter gives uniformly better results with less cost, and less wear and tear.

SCHEME FOR QUALITATIVE BLOWPIPE ANALYSIS.

BY A. J. MOSES.

In the following scheme the tests are grouped in an order favorable to rapid work, and the attempt has been to give an amount of detail that will suffice for most analyses. Substances of unusual complexity will need special treatment that the scheme does not pretend to outline, and at all times successful work will be probable only when the analyst has previously acquired a fair knowledge of the reactions of the simple oxides.

The substance may contain: Al, NH_3, Sb, As, Ba, Bi, Bo, Br, Cd, Ca, Cl, Cr, Co, Cu, F, Au, I, Fe, Pb, Li, Mg, Mn, Hg, Mo, Ni, P, K, Se, Si, Ag, Na, Sr, S, Te, Sn, Ti, W, U, V, Zn.

TESTS UPON THE UNROASTED SUBSTANCE.

1. In narrow glass tube closed at one end.

Heat in the flame of an alcohol lamp, at first gently and then to redness. Note all changes.

Moisture in the upper part of tube,	H_2O
Odorless gas that assists combustion,	O
Pungent gas that whitens lime water,	CO_2
Odor of prussic acid,	CN
" of putrid eggs,	H_2S
" that suffocates, fumes colorless,	SO_2
" " " violet,	I
" " " brown,	Br
" " " greenish,	Cl
" " " etch the glass,	Fl
" of nitrous acid, fumes reddish brown,	N_2O_5
" of ammonia, fumes colorless or white,	NH_3
Sublimate white, fusing yellow,	$PbCl_2$
" " and volatile,	NH_3 (salts)
" " yellow hot, infusible,	HgCl
" " " fusible,	$HgCl_2$
" " fusible, needle crystals,	Sb_2O_3
" " volatile, octahedral crystals,	As_2O_3
" " fusible, amorphous powder,	TeO_2
" mirror-like, collects in globules,	Hg
" " does not collect in globules,	As,Cd,Te
" red when hot, yellow cold,	S
" dark red when hot, reddish-yellow cold,	As_2S_3
" black, when hot, reddish-brown cold,	Sb_2S_3
" black but becomes red when rubbed,	HgS
" red to black, but becomes red when rubbed,	Se
Color of substances changes	
from white to yellow, cools yellow,	PbO
" " yellow, cools white,	ZnO
" " dark yellow, cools light yellow,	Bi_2O_3
" " brown, cools yellow,	SnO_2
" " brown, cools brown,	CdO
" yellow or red to darker, cools green,	Cr_2O_3
" red to black, cools red,	Fe_2O_3
" blue or green to black, cools black,	CuO

2. In narrow glass tube open at both ends.

Place the assay near the lower end of the tube and heat gently and then strongly increasing the air current by holding the tube more and more nearly vertical.

Odor that suffocates, ...	SO_2, indicating	**S**
" of rotten horseradish, ...	SeO_2, "	**Se**
" of garlic, ...	As_4O_6, "	**As**
Sublimate white volatile octahedral crystals,	As_2O_3, "	**As**
" " non-volatile powder, . .	Sb_2O_4, "	**Sb**
" " non-volatile fusible powder,	TeO_2, "	**Te**
" " non-volatile fusible powder,	$PbSO_4$, "	**PbS**
" gray red at distance, . . .	SeO_2, "	**Se**
" yellow hot, white cold, blue in R. F.,	MoO_3, "	**Mo**
" brown hot, yellow cold, fusible, .	Bi_2O_3, "	**Bi**
" metallic mirror,	"	**Hg**

3. Alone on charcoal.

Heat with gentle O. F.

Sb.—Volatile white coat that disappears in R. F. tinging the flame green.

As.—Garlic odor and a faint white coat that disappears in R. F., tinging the flame azure blue.

Se.—Horseradish odor and a steel gray coat that disappears in R. F., tinging the flame azure blue.

Te.—White coat with red or yellow border that disappears in R. F., tinging the flame green.

Change to gentle R. F.

Cd.—Brown coat surrounded by peacock tarnish. The coat heated in a closed tube with $Na_2S_2O_8$ gives a bright yellow mass.

Heat strongly in both flames and, if the presence of Te is suspected, place a bit of porcelain so that the fumes pass between it and the coal (or test a separate portion on a plaster tablet).

As, Sb and **Cd** may give stronger tests.

Zn.—White not easily volatile coat, bright green with cobalt solution.

Sn.—White non-volatile coat close to assay, blue green with cobalt solution.

Te.—Moisten the film, which forms on the porcelain, with concentrated H_2SO_4 and heat gently; the acid will be colored a fine red.

Dissolve *any* coat that forms in Ph. S. and treat on coal with R. F. and tin.

Sb or **Bi.**—A dark gray to black bead.

White coats may form from Mo Pb Bi or alkalis, yellow coats from Pb or Bi, brown or red coats from Cu or Mo, and the ash of the coal may be white or red. If these coats interfere with the Sb test, the Pb and Bi may be held back by adding a little boracic acid.

4. With soda on coal.

Make a paste with the substance, soda, water and charcoal dust, and heat strongly with R. F.

As and **Cd** should be noticed here even in small amounts.

If *any* coat forms, moisten it with cobalt solution and blow a strong blue flame *on the substance.* **Zn.**—Bright green. **Sn.**—Blue green,

Dig up the coal containing the soda and place it upon a silver coin, moisten, crush and heat.

S, Se, or **Te.**—The coin will be blackened.

If the soda effervesces during fusion, look for SiO_2 or TiO_2. Examine it also for metallic particles and note whether they are *e.g.*, malleable, magnetic, brittle, red, etc.

5. With bismuth flux.

Treat the substance on coal to remove the excess of Sb, As and Hg, by gentle O. F. and excess of Cd by gentle R. F. Mix with an equal volume of the flux, and heat gently upon a plaster tablet.

Pb.—Yellow coat of iodide at distance, yellow oxide nearer.

Bi.—Red coat of iodide at distance, yellow oxide nearer.

Bi and **Pb.**—Orange coat of iodide at distance.

Make a similar test on coal, first moistening the coal near the assay with cobalt solution. Blow a strong flame upon the substance.

Sn.—A bluish-green coat (which is not injured by the Pb and Bi coats).

White coats may form of KI or K_2SO_4, and at times the red iodide of Bi is fringed with the yellow of Bi.

6. In matrass with soda.

Mix the substance thoroughly with soda, and heat.

Hg.—Metallic mirror that can be collected into globules.

Cd, Te and **As.**—Metallic mirrors that cannot be collected into globules. Break matrass and heat mirror for odor of As_2O_3.

NH_3.—Odor of ammonia.

7. In matrass with $KHSO_4$.

Mix the substance with $KHSO_4$ and heat gently.

Br.—Brown fumes. Gives greenish blue flame in Ph. S. bead with CuO.

I.—Violet " " emerald green " " " " " "

Cl.—Greenish " " azure blue " " " " " "

N_2O_5.—Brown fumes, recognizable by odor.

Fl.—The glass of matrass will be etched. If a moistened strip of Brazil wood paper be inserted at one end of an open tube, and

at the other a mixture of powdered phosphorus glass and substance be fused, the paper will be made *straw* color, and the glass etched, and made dull and cloudy throughout or in patches.

8. With dilute acid.

Heat substance gently with dilute HNO_3 or HCl.

CO_2.—Effervescence continuing after flame is removed (H_2S and Cl are sometimes evolved with HCl, but may be recognized by their odors).

TESTS UPON THE ROASTED SUBSTANCE.

If the substance has been proved to contain no As, Sb, or S, proceed with No. 9, but if not, submit the substance to a slow heating in the O. F. to drive off S, As, Sb, etc., and thus leave the metals mainly as oxides. Turn the material occasionally, and if it agglomerates, repulverize and again roast. Continue till no noticeable fumes are given off.

9. In phosphorus salt bead.

Note all the changes with small and larger amounts of the substance dissolved, and with treatment in both O. F. and R. F.

The changes and their simpler confirmations are as follows:

	In R. F. Cold.	In O. F. Hot.	In O. F. Cold.	Confirmation. Soda bead O. F.
Mn.	Colorless	Brown	Violet	Bluish green.
Cr.	Green	Reddish	Green	Yellow
Ur.	"	Yellow	"	Brown
Mo.	"	Greenish	Colorless	White
V.	"	Dk. Yellow	Lt. Yellow	"
Co + Fe.	Dull Green	Green	Green	"
Co.	Blue	Blue	Blue	On coal with Sn.
W.	"	Yellow	Colorless	Green
Ti.	Violet	"	"	Violet
Ni.	Yellow	Brown	Yellow	Colorless
Fe.	Brown or Red	Dark-Yellow	Light-Yellow	Green to Colorless
Fe + Ur.	"	Red to Yellow	Greenish	Green
Fe + W.	"	"	Light Yellow	Blue to Wine Color
Fe + Ti.	"	"	"	Violet
Cu.	Opaque Red or Green	Green	Blue	Opaque Red

SiO_2.—The hot bead cannot be made perfectly clear, but is semi-transparent.

Touch hot bead to $NaNO_3$.

Mn.—Violet color.

If Cu or Co obscure the tests treat as in No. 11.

The absence of Mn and Ni is not proved until special tests have been made.

The SiO_2 test is best made upon a small fragment of the substance. The bases of most silicates dissolve, leaving a translucent mass or "skeleton" of the general shape of the fragment, and visible in both the hot and cold beads.

10. Reduction color tests.

Saturate two Ph. S. beads with the substance in O. F., treat one of them on coal with Sn and strong R. F., pulverize and dissolve separately in cold dilute (1-4) HCl with the addition of a little Sn. Let the solutions stand for some time and then heat them to boiling.

	The Oxidized Bead Yields		The Reduced Bead Yields	
	In Cold Solution.	In Hot Solution.	In Cold Solution.	In Hot Solution.
W.	Blue	Deep Blue	Deep Blue	Deep Blue
Mo.	Green to Blue	Wine Brown	Brown	Faint Brown with Black Precipitate.
Ti.	Faint Violet	Violet and Turbid	Violet and Turbid	Violet
V.	Bluish Green	Green	Green	Green
Cr.	Green	"	"	"
Ur.	"	"	"	"

11. Separation of Ni, Co and Cu.

If the absence of Ni not proved, or Co obscures the tests, dissolve the substance in borax on coal to saturation, and treat for five minutes in hot R. F., by which the Cu, Ni and some of the Co will be reduced. If much Pb or Bi is present, the reduced button will be large enough to handle, but if not, add either a small (50 m.g.) gold button with a little lead, or, if much Cu is present, add only lead.

Separate the button and the slag (saving both) and scorify the button with BO_3 to remove the lead, and then with frequently changed Ph. S. The metals which have united with the gold or lead will be successively oxidized, and their oxides will color the Ph. S. in the following order:

Co.—Blue, hot; blue, cold. May stay in the slag.

Ni.—Brown, hot; yellow, cold. May give green with Co or Cu.

Cu.—Green, hot; blue, cold. Made opaque red by Sn and R. F.

The slag should contain the more easily oxidizable metals, and be free from Cu, Ni and Ag. Test a portion with Ph. S. and Sn to prove absence of Cu. If present it must be removed by further reduction with Pb. Pulverize the slags and dissolve a portion in Ph. S. and treat as in No. 9.

12. Fusion for silver.

Fuse with test lead and borax glass. Continue the blast about five minutes, using R. F. Separate slag and button, and scorify the button with fresh borax. Transfer the button to a cupel and blow a gentle oxidizing flame across it. If the litharge is dark or the button freezes while still large, scorify again with borax and add more lead until there remains only:

Ag.—A bright *spherical* button, not altered by further blowing. (If the button is flat, add test lead and again cupel.)

Au.—A residue after boiling the Ag in HNO_3.

13. Substance with cobalt solution.

Heat the substance strongly on coal, cool and moisten with cobalt solution.

Al. Pink, reheated, is blue. **Mg.** Pink to blue, reheated is pink.
Ba. " " brown. **Ca.** Blue to green, " gray.
SiO_2." " faint blue. **Sr.** Blue to brown, " gray.

Violet may be $Mg_2P_2O_7$. There may also be blues from fusible compounds, and greens from TiO_2, ZnO, SnO_2.

14. Flame tests.

Moisten a clean platinum wire with HCl, dip it in the substance and heat in the blue flame, both at the tip and near the wick. Note the color of the flame with the naked eye and through a cobalt blue glass.

	Alone.	Through Blue Glass.
Na.	Yellow	Invisible.
Ba, Mo and B.	Yellow green.	Bluish green.
Ca.	Yellow red.	Greenish gray.
Sr and Li.	Crimson.	Violet.
K.	Violet.	Purple red.
Cu, As, Pb, Se.	Blue	Blue.

Make similar test with H_2SO_4. The improved tests will be:

Bo.—Yellow green.

P.—Instantaneous blue green, that may be overpowered by the green of Bo. In such a case place a piece of Mg wire in a closed tube, and cover the wire with a mixture of soda and the substance. Heat till the mass fuses, cool and add water.

P.—Evolution of phosphuretted hydrogen.

Make a paste of boracic acid flux and substance, and treat at tip of the blue flame. Just after the water is driven off there may be:

Bo.—Yellow green. **Li.**—Pink to Carmine.

Dissolve substance in Ph. S. to excess, add NaCl and heat in flame gently.

Cu.—Azure blue flame.

Pb.—Azure blue flame at very high heat.

THE COMPARATIVE DELICACY OF SOME QUALITATIVE TESTS.

BY J. S. C. WELLS.

I HAVE so often been shown tests by students, and asked if they indicated any appreciable quantity of the substance tested for, that I have thought it might be of interest to know just how delicate some of the more important tests are.

I have begun with the metals of the fifth group (according to Fresenius), and the accompanying tables show the results obtained. Many tests might, no doubt, have been carried even farther than shown in table by using larger quantities of liquid and allowing them to stand for a longer time. My idea, however, was to obtain results, such as any student might, with the ordinary apparatus used by him. For this reason the tests were all made in the ordinary 6-inch test-tube, and, unless otherwise stated, were not let stand more than five minutes.

It will be seen from the table that nearly all show, even in very dilute solutions, and that some of them, such as the precipitation of lead by H_2S, are wonderfully delicate. It should be remembered that the results given were obtained in solutions containing nothing but the substance tested for and the reagent; no

foreign substances being present. The results in column I show the point beyond which it was impossible to distinguish distinct particles of the precipitate. After passing this point the reaction was indicated by a mere cloudiness or color. In column II is shown the extreme limit of the test, that is, the most dilute solution in which any reaction was obtainable. In order to get a clear idea of how dilute such solutions are, it may be well to state that one part in one million is equivalent to 1 grain in 17 gallons.

SILVER (Ag.).

Reagent.	I. Part of substance.	I. Parts of water.	II. Part of substance.	II. Parts of water.
NH_4Cl,	1	20,000	1	250,000
HCl,	1	20,000	1	250,000
KBr,	1	20,000	1	200,000
KI,	1	5,000*	1	200,000
H_2S,	1	5,000	1	800,000
$K_2Cr_2O_7$,	1	3,000	1	3,000

MERCURY (Hg).

Hg_2O.

NH_4Cl,	1	25,000	1	200,000
HCl,	1	25,000	1	200,000
H_2S,	1	5,000	1	1,000,000
NH_4OH,	1	25,000	1	25,000
$SnCl_2$,	1	50,000	1	200,000
$K_2Cr_2O_7$,	1	20,000	1	100,000

HgO.

H_2S,	1	2,000	1	1,000,000
NH_4OH,	1	4,000	1	4,000
$SnCl_2$,	1	50,000	1	200,000
Cu,	1	10,000†		

LEAD (Pb).

HCl,	1	500	1	500
NH_4Cl,	1	600	1	600
H_2S,	1	20,000	1	1,000,000‡
H_2S in KOH solution,		.....	1	1,000,000‡
H_2SO_4,	1	10,000	1	20,000§
$K_2Cr_2O_7$,	1	10,000	1	100,000

* Only shows on standing some minutes.

† Shows in solution of 1–100,000 after standing four hours.

‡ Seen only on looking down the tube.

§ Only on standing a few minutes.

BISMUTH (Bi).

H_2S, ...	1	13,000	1	1,000,000
NH_4OH, ...	1	10,000	1	12,000*
H_2O,†	1	10,000	1	90,000
K_2SnO_2‡	1	40,000	1	90,000

COPPER (Cu).

H_2S, ...	1	2,000	1	1,000,000
NH_4OH, ...	..	.....	1	80,000
K_4FeCy_6, ...	1	2,000	1	1,000,000

CADMIUM (Cd).

H_2S, ...	1	4,000	1	200,000
$H_2S + HCl$,§ . .	1	20,000	1	200,000
K_4FeCy_6, ...	..	.....	1	4,000

QUALITATIVE LABORATORY, SCHOOL OF MINES.

INTER-COLLEGIATE BOAT RACING.‖

BY PROFESSOR W. P. TROWBRIDGE.

THE question has been frequently discussed among those who take a general interest in college sports, whether the excessive training for long-distance boat races, and the violent and long-continued muscular and nervous exertions incident to these contests, do not in reality result in unnecessary and hurtful exhaustion during a race, and frequently in permanent injury to the contestants. It is quite certain that boat races with 4-mile courses are extreme tests of physical endurance, as well as of strength and skill; and it is well to ask whether a certain kind of collegiate supremacy, an exciting holiday for assembled crowds of students and their friends, the momentary exultation over a college victory, are not too

---

* Only on standing a few minutes.

† This test was made on a solution of $Bi(NO_3)_3$ in presence of NH_4Cl.

‡ This is the test with KOH and $SnCl_2$, yielding Bi_2O_2.

§ I found that the addition of a few drops of HCl made the precipitate separate much better than it would in either alkaline or neutral solutions.

‖ From the New York Evening Post.

dearly bought when the price paid is the health and, perhaps, the life's usefulness of a student.

As long, however, as one college challenges another, whether it be to a boat race, a ball match, or a foot race, we may expect that the challenge will be accepted; the faculties being generally not only willing but ready backers, certainly the most enthusiastic applauders—after a victory. But since all sports or friendly contests must take place under established rules, it is a very proper subject for discussion whether the distance to be rowed in our inter-collegiate boat races may not be changed to three miles, without the slightest risk of rendering these contests less exciting or diminishing the value of the victory, while at the same time the long and extremely rigorous training which is now necessary might then be diminished somewhat, and the exhausting effect on the rowers during the week of the races be avoided. It is a matter of experience, I believe, that a race is practically decided at the end of the third mile, the occasions on which the crew that leads at the end of the third mile is finally beaten being very rare. This means that in everything that brings victory, strength, skill, coolness, and endurance, a three-mile course is all that is necessary. The fourth mile adds almost complete exhaustion, without changing the result, but it is the fourth mile that demands so much more rigorous training and previous work.

A lesson might be taken from the rules of horse racing, where such complete over-fatigue on the part of the horse is not tolerated, and would indeed be looked upon by spectators as a sort of cruelty to animals, not unlikely to bring about perhaps, the official interference of Mr. Bergh. The laws of fatigue and refreshment, and of total exhaustion, applicable to muscular exertion, are special examples of a universal law as immutable and infallible as any other law of nature. One of the most interesting of all the developments of animal mechanics is found in the discovery that the law which governs the expenditure of energy in artificial motors is not only analogous but identical with that which applies to animal or muscular energy. This identity is most clearly shown in comparing the consumption of a given amount of coal in driving a vessel through the water through the medium of a steam-engine, with the consumption or exhaustion of a given amount of muscular energy in propelling a boat. It is well known that the resistance to the motion of a boat in the water is proportional to the square

of the velocity; and as the work performed (or coal consumed) in a unit of time—one hour, for example—is proportional to the resistance multiplied by the velocity or speed per hour, it follows that the consumption of fuel is proportional to the cube of the velocity. It is also known that a given quantity of fuel is capable of doing only a fixed amount of work, whatever be the rate of combustion or speed with which the vessel is driven. The number of hours required, therefore, for the consumption of equal quantities of fuel in propelling the same vessel through the water at different velocities, will be proportional inversely to the cubes of the velocities, while the space passed over will be inversely proportional to the squares of the velocities. Suppose a steam vessel with a given amount of coal on board to start on a passage of one hundred miles, the speed to be five miles per hour. The time required to make the trip will be twenty hours, and the coal is supposed to be just sufficient for this voyage with this velocity. Suppose again the same vessel to undertake the same trip with the same amount of coal, but with a velocity of ten miles per hour. The result will be that the coal will all be consumed in two and one-half hours, one-eighth of the time, and the boat will only make twenty-five miles of the distance; it must then become helpless and unable to go further unless more fuel is supplied.

This is an important law, which, if it be found applicable to the expenditure of muscular energy, should be heeded by every one: It is that the time of exhaustion is inversely as the cube of the speed with which work is performed; when resistances overcome are proportional to the square of the velocity. In ordinary daily work, however, the law takes a somewhat different form. In walking, for instance, the resistance is not proportional to the square of the speed, but to the speed or velocity simply; the exhaustion being that of raising the body about one and two-tenths inches at each step against the resistance of gravity and inertia, the latter being proportional to the velocity with which the body is lifted. In walking, therefore, the time of exhaustion is inversely proportional to the square of the velocity, and the space passed over inversely to the velocity.

The law that the time of exhaustion is inversely as the cube of the velocity is, however, strictly applicable to the boat race, since the resistance of the boat is proportional to the square of the velocity, and as the test of victory is the speed, it follows that the

price of victory is a certain degree of exhaustion. How great that exhaustion shall be depends on the length of course. Unfortunately it is not the fatigue of the muscles of the legs, arms, and back that are most concerned, but those of the respiratory and circulatory organs, the lungs and the heart, that are involved. It is well known that the action of a muscle in contracting is accompanied by a destruction of tissue, a true combustion in one sense, carbonic acid, water, and other products being formed, and that the refreshment of the muscle consists in the rejection of these products, and a building up of tissue through the blood, which flows to the muscle from the heart. This refreshment is essential to continued action. Muscular work, therefore, involves both fatigue and refreshment as well as strength or muscular force. It has been ascertained by careful estimates that the average laborer in various callings performs work equivalent to about 350 foot-tons in ten hours, *i. e.*, work equivalent to raising 350 tons one foot high in ten hours. But the day laborer finds many intervals of rest during his work; each exertion is usually followed by a short interval of rest, sufficient for the refreshment of the muscles, and he might thus continue his exertions almost indefinitely were it not that the peculiar and essential kind of rest which is found in sleep demands its share of his time. Moreover, in ordinary labor all of the muscles of the body are seldom in action at once, the diversity of effort permitting certain muscles to rest temporarily while others are engaged.

The boat race involves the action of all the muscles, those of the legs, arms, and shoulders, as well as of the back; and hence the demands on the heart and lungs are the greatest possible. The work which a rower performs in each minute of a four-mile race is easily calculated. The distance—21,120 feet—is traversed in about twenty-one minutes. The speed is, therefore, practically about 1000 feet per minute. At this speed the resistance to the boat in the water is about 75 pounds. This resistance has been determined experimentally, as well as theoretically, in England, the average result being 75 pounds. The work per minute for eight men is, therefore, 75,000 foot-pounds, or 9375 foot-pounds (4.2 foot-tons) for each man per minute.

At the rate of 350 foot-tons in ten hours, the day laborer performs work at the rate of only 6-10 of a foot-ton per minute. The rower in the boat race, therefore, performs work each minute

equivalent to the work of seven strong laborers, or at the rate of nearly one-third of a theoretical horse-power each minute during the race.

The question now recurs: For how long should these extraordinary efforts be sustained! Four miles in distance and twenty-one minutes in time mark extreme limits of endurance, according to all experience in boat racing. And if races are practically decided at the end of the third mile, or whether they are so decided or not, the fourth mile is a test, not of skill and muscular strength, but of the hearts and lungs of the crews.

This is rather serious business. Is it quite rational to make the ultimate endurance of these vital organs in a dozen young men a matter of sport and amusement? The muscles of the heart and lungs are among those whose action is quite voluntary, although they are called involuntary muscles. They are the willing and obedient servants who need no prompting from the will, but who, sleeping and waking, guard and sustain animal life. But the laws of fatigue and refreshment for these muscles are the same as for others. Long-continued excessive violent action must impair their efficiency.

It is hardly to be expected that any boat crew will initiate a movement to reduce the length of course from four miles to three; to use an appropriate expression, they "would die first." Such a movement might be looked upon as a confession of weakness. But when the suggestion comes from an outsider, it is made to all alike, and may at least be discussed with possible profit.

ADDITIONS TO THE COLUMBIA COLLEGE LIBRARY IN THE DEPARTMENT OF NATURAL SCIENCE, USEFUL AND FINE ARTS. APRIL AND MAY, 1887.*

I. ASTRONOMY.

SCHURIG, R.—Himmels-Atlas. F. Leipzig. 1886.

II. BOTANY AND ZOOLOGY.

SAPORTA AND MARION.—L'évolution du régne végétal. 8vo. Paris. 1881.

RATTAN, V.—Analytical Key to West-Coast Botany. 12mo. San Francisco. 1887.

KUNTZE, O.—Schutzmittel der pflanzen. 8vo. Leipzig. 1877.

LEDEBOUR, C. F.—Flora rossica. 4 vols. 8vo. Stuttgart. 1842–53.

MUELLER.—Key to System of Victoria Plants. 12mo. Melbourne. 1885.

BEAL, W. J.—Grasses of North America. Topeka. 8vo. 1887. (*Gift of Torry Bot. Club.*)

PAINE, J. A.—Catalogue of Plants in Oneida County. 8vo. Utica. 1864.

SARGENT, F. L.—Guide to Recognition of Cryptogams. D. Cambridge. 1886. (*Gift of Dr. N. L. Britton.*)

LINDENBERG, J. W. B.—Monographie der riccien. Sq. 4to. (*Gift of Dr. N. L. Britton.*)

TAYLOR, T.—Marchanticis. Sq. 4to. 1835. (*Gift of Dr. N. L. Britton.*)

HUBERSON, G.—Precis de Microphotographie. 12mo. Paris. 1879.

GIRARD. J.—Le Monde Microscopique des eaux. 16mo. Paris. 1872.

VIALLANES.—La photographie appliquée aux études Microscopiques. 12mo. Paris. 1886.

III. CHEMISTRY.

IV. ENGINEERING.

KENNEDY, A. B. W.—Mechanics of Machinery. 12mo. London. 1886.

CALLON, J.—Lectures on Mining. Vol. 3. 8vo., and Atlas. London. 1886.

INDIA, Great Trigonometrical Survey of. Sq. 4to. 1886.

NEW ZEALAND.—Report on Mining Industry. 8vo. Wellington. 1887.

MICHIGAN State Board of Health Reports. 13 vols. 8vo. Lansing. 1873–85.

Vital Statistics. 15 vols. 8vo. Lansing. 1870–84. (*Gift of State Board.*)

* Reader's tickets can be obtained without difficulty by any one wishing to refer to books in the library.

NEW JERSEY State Board of Health Reports. 6 vols. 8vo. Trenton. 1878–80, 1883–86. (*Gift of State Board.*)
TRANSACTIONS of the Institution of Surveyors. 18 vols. 8vo. London. 1868–86. (*Gift of Prof. W. R. Ware.*)

V. GEOLOGY.

O'REILLY, J. P.—Alphabetical Catalogue of Earthquakes. F. Dublin. 1886.
PRUSSIA.—Geologische Landesanstalt Jahrbuch. 8vo. Berlin. 1886.
KARSTEN, H.—Géologie de l'ancienne Columbie. F. Berlin. 1886.

VI. MATHEMATICS.

HOUEL, J.—Cours de Calcul infinitesimal. 2 vols. 8vo. Paris. 1880.
JORDAN, M. C.—Cours d'analyse de l'école polytechnique. 8vo. Paris. 1882.
PINETO, S.—Table de Logarithmes Vulgaires. 8vo. St. Petersburg. 1871.
MATZKA, W.—Determinanten. Prague. Sq. 4to. 1877.
CLEBSCH, A.—Theorie der binären algebraischen formen. 8vo. Leipzig. 1872.

VII. METALLURGY.

VIII. MINERALOGY.

BOMBICCI, L.—Mineralogia. 16mo. Milano. 1885.
VOGELSANG, H.—Die Krystalliten. 8vo. Bonn. 1875.
SPEZIA.—Minerali all' esposizione generale. Italiana. 1884.
FOUQUE AND LEVY.—Synthese des Mineraux et des roches. 8vo. 1882.

IX. PHYSICS AND METEOROLOGY.

X. MISCELLANEOUS.

DAVIS, G. E.—Sizing and Mildew in Cotton Goods. 8vo. Manchester. 1880.
BARY, A. de.—Vergleichende Morphologie und Biologie. 8vo. Leipzig. 1884.
EPITOME of the Newer Materia Medica. 8vo. Detroit. 1886.
KLEIN AND SMITH.—Atlas of Histology. F. London. 1880.
MARSHALL, A. M.—Frog. 2d ed. 12mo. London. 1885.
LANDOIS, L.—Human Physiology. 2 vols. 8vo. London. 1886.
SCHLESINGER, R.—Examen microscopique des textiles. 8vo. Paris. 1875.
BROWN, J. C.—Study of Modern Forest Economy. 12mo. Edinburgh. 1884. (*Gift of J. C. Brown.*)
Schools of Forestry. 8 vols. 12mo. Edinburgh. 1883–87. (*Gift of J. C. Brown.*)
SMITH, T. R., AND SLATER.—Architecture, Classic and Early Christian. 8vo. N. Y. 1882.
SCOTT, L.—Sculpture, Renaissance and Modern. Pamphlet. N. Y. 1886.
WILMOT-BUXTON.—English Painters. 8vo. 1883.
REDFORD, G.—Manual of Sculpture. 8vo. 1883.
SMITH, G. W.—Painting, Spanish and French. 8vo. 1884.

INDEX OF CURRENT LITERATURE RELATING TO NORTH AMERICAN GEOLOGY.

BY F. J. H. MERRILL.

CANAAN, Columbia County, N. Y. Palæontological Observations on the Taconic Limestones of. William B. Dwight. *Am Nat.*, vol. xxi., p. 270.

CANADA, Geological Survey of. Report for 1885. *Am. Journ. Sci.*, III., xxxiii., p. 316.

FLORIDA, Geological Survey. *Science*, vol. ix., p. 447.

MAINE, Terminal Moraines in. George H. Stone. *Am. Jour. Sci.*, III., xxxiii., p. 378.

MANHATTAN ISLAND, Eozoonal Rock of. L. P. Gratacap. *Am. Jour. Science*, III., xxxiii., p. 374.

NEW JERSEY, Geological Survey of. Report for 1886. *Eng. and Min. Jour.*, vol. xlii., p. 271.

NIAGARA RIVER. Age of. J. W. Spencer. *Am. Nat.*, vol. xxi., p. 269.

ONTARIO, A Landslide at Brantford, illustrating the Effects of Thrusts upon Yielding Strata. J. W. Spencer. *Am. Nat.*, vol. xxi., p. 267.

PACIFIC COAST. Notes on the Glaciation of the. G. F. Wright. *Am. Nat.*, vol. xxi., p. 250.

QUEBEC GROUP, The. A. R. C. Selwyn. *Science*, vol. ix., p. 267.

TACONIC Question Restated, The. T. Sterry Hunt. *Am. Nat.*, vol. xxi., pp. 238, 312.

TACONIC Rocks and Stratigraphy. J. D. Dana. *Am. Jour. Sci.*, III., xxxiii., pp. 270 and 393.

TEXAS. The Topography and Geography of the Cross Timbers and the surrounding regions in Northern. R. T. Hill. *Am. Jour. Sci.*, III., xxxiii., p. 291.

NOTES AND ABSTRACTS.

Burlington Brake-Tests.

The engineering profession is well aware that an elaborate series of tests have been conducted lately to try the relative merits of the car-brakes in the market, particularly in their application to long freight trains.

The results cannot but be of great value to the railway service of the country, and any information on the subject must prove interesting to engineers.

The following notes, taken on the field, have been forwarded to the QUARTERLY, and are published in advance, with the intention of following them with a more complete and studied article upon the subject in a later issue.

One point that seems very forcibly brought out by the tests, is the necessity of using some instantaneous means of braking long trains, and electricity appears to fill the demand. A comparison of tests, made in 1886, with the Westinghouse (non-electric), on a train of fifty empty cars, with a similar test made this year, but with electric attachments, shows the distance covered in stopping with the electric brake to be about 45 to 50 per cent. of that without the electric device, and the time consumed about one-half. The tests of the present year, without the electric device, show greater differences.

The experiments with the slideometer to determine the relative shock still further emphasizes the value of electricity in applying the brake to long trains. In stops made with the electric appliances no movement of the slideometer of any consequence was noticed, while without its use the shock to the rear cars was very severe, the greatest movement of the slide recorded being 103 inches. As was remarked by the engineer in his letter enclosing this report, one must be present to appreciate what a 103-inch bump means. The Convention, in its circular states, that a 12-inch bump is objectionable as being dangerous to stock.

The Carpenter, which is an electric brake, and the Westinghouse, with the electric device, are competing very closely for the lead in the contest.

Many of the records, particularly among those of tests with long trains, show results in favor of the Carpenter brake. . . . .

Under the auspices of the Master Car Builders Association tests of freight car-brakes were held at Burlington, Ia., commencing May 9th, 1887. The following competitors were present, each with a train of fifty standard box cars and an engine, as required by the committee in charge. Eames Vacuum Brake Co., The Westinghouse Air Brake Co., The Car-

penter Electric Air-Brake, The Hanscom Brake Co., and the Card Electric Brake Co.

The general tests consisted: 1st, of emergency stops, with trains of fifty empty cars, over the course prescribed, making four stops. Nos. 1 and 2 on a level, and Nos. 2 and 3 on down grade of 53 feet per mile. Nos. 1 and 3 to be made as near as possible at 20 miles per hour, and Nos. 2 and 4 as near as possible at 40 miles per hour.

2d. Emergency stops, with mixed car trains of fifty cars, two-thirds of the cars loaded to full capacity and one-third empty. Seventy-five per cent. of the empty cars in the front half of the train. The same stops were made as with the empty trains, except stops 2 and 4 were from a speed as near 30 miles per hour as possible.

3d. Fifty empty car-train with hand brakes and engine and tender automatic brakes; four emergency stops, same as above.

4th. Fifty mixed car-train to be let down a grade of 53 feet per mile, three miles long. Speed of 20 miles per hour, at top of grade, to be reduced to 15 miles per hour as soon as practicable, and maintained without material variation all the way down the grade.

5th. Fifty mixed car-train once over the course. Brake shoes having slack from ½-inch to ¾-inch, each form emergency stops same as in 2d.

6th. Four emergency stops with engine and dynamometer car only, the latter not provided with brakes; on level and on 53-foot grade, at 20 and 40 miles per hour.

Special tests were made to determine the train resistance and to determine the action of the automatic apparatus in case of break away.

In all these tests a dynamometer car was placed in front end of train with complete recording mechanism. In the middle box-car of each train autographic records were made showing the tension on brake-rod and the speed during each stop. The shocks during the stops were measured by the movement of a turned iron weight, free to slide in a planed deal trough placed horizontally in the rear car of each train. A movement of more than 12 inches was considered objectionable by the Committee, as indicating a shock violent enough to injure stock.

The following figures are given as the records of the various stops made to date. These figures are believed to be substantially correct, though still subject to revision. The report of the Committee will not be ready for some time and until then no official figures can be obtained.

Both Westinghouse and Eames trains were provided with supplemental electric devices and it will be understood that when "electric" is specified the stops were made with the assistance of the electric devices.

Fifty Empty Car Trains.—Emergency Stops.

	Stop 1, on level.			Stop 2, on level.			Stop 3, 53 ft. grade.			Stop 4, 53 ft. grade.		
	Speed, miles per hour.	Distance, feet.	Time, seconds.	Speed.	Distance.	Time.	Speed.	Distance.	Time.	Speed.	Distance.	Time.
W'tinghouse electric.	22	181	8	36½	453	14	20	170	8¼	40½	614	16
" "	21½	165	7	39	475	14½	21½	159	8¼	41½	656	16
Eames electric.....	22	253	10¾	41	616	16½	21	251	13	41	785	21
" "	21½	326	14									
" "	20½	343	16¾				21	414	19¼	38½	634	17¾
Carpenter.....	22½	140	7½	32½	300	11	23	173	9	41¾	565	16
"	23	150	6¾	34	312	12	21½	143	7½	41	590	17¾
"	23	133	6	36	330	11½	22	136	6¾	41½	572	16½
	(*a*)											
Westinghouse	19¼	214	11									
	(*b*)			(*c*)								
"	17¼	184	9¾	35¼	586	17						
	(*d*)			(*e*)			(*f*)			(*g*)		
"	20	521	24¼	36½	1007	27¾	21½	488	21	39¼	1365	33½
	(*h*)											
Eames.....	21	363	15½	38	884	23	20	378	17¾	42	1179	27¾
	(*i*)											
"	21½	363	17¼	38¼	872	19½	21½	405	22	42	1162	20½
	(*k*)											
"	23½	403	17	40	937	23¼	20½	365	18¾	40½	1082	25
Card electric.....	20	300	17	36	1050	38½	20½	596	32¾	37¼	1703	51

In stops made with the electric appliances no movement of the slide-ometer of any consequence was noticed. In stop (*a*) with Westinghouse automatic (non-electric), a bump causing a movement of 70⅜ inches on slideometer was experienced in last car; draw-bar in rear car broken. Stop (*b*), a bump of 103 inches was recorded. Stop (*c*), 70½-inch bump was experienced, the train breaking in two. The slideometer record for remaining stops with Westinghouse automatic were: (*d*) 2", (*e*) 11¾", (*f*) 13¾", (*g*) 14".

The slideometer records with the Eames automatic were as follows: run (*h*), 18⅛", 15⅜", 20¼", 16⅝"; (*i*), 20", 19½", 22", 20½"; (*k*), 24¼", 20¾", 25½", 23¾".

The Eames and Westinghouse trains were provided with close couplers, the former using the "Boston," and the latter the "Janney." The Carpenter train used ordinary link and pin loose coupling.

Fifty Mixed Car Trains (Thirty-three Cars, Loaded Full Capacity), —Emergency Stops.

	Stop 1, on level.			Stop 2, on level.			Stop 3, 53 ft. grade.			Stop 4, 53 ft. grade.		
	Speed.	Distance.	Time.	Speed.	Distance.	Time.	Speed.	Distance.	Time.	Speed.	Distance.	Time.
Carpenter	21½	193	11	34¼	572	19¾	21¼	227	13	36½	870	28¾
"	19½	132	9¾	30¾	396	15½	22	240	13¾	33½	717	25¼
W'tinghouse electric.	20¼	202	11¼	31	504	19¼	21	235	13½	32	643	22¼
" "	20½	202	11¼	31½	501	18	21¾	246	13¾	32¾	640	21½
Eames electric	19	205	12	29	462	18	20	242	13½	30	623	22½
" "	15	148	11	31	576	21	22¾	339	17	34	878	27¾
Engine and Dynamometer Car.—Emergency Stops.												
Westinghouse	20½	248		41	1035	30	20	301	15½	40	1323	37½
"	21	286	16½	41½	968	28½	21	259	14½	41½	997	31½
Eames	21½	336	16¾	40¾	1111	31	23½	455	21½	40¾	1374	36¼
"	23¾	425	20½	39¾	1060	21½	22¾	418	21¾	40½	1331	38¼
Carpenter	21	264	14	41½	1283	35½	21½	367	17½	39	1505	44
"	23½	231	12	40	730	23	20	209	12	35	590	21½
"										45	1177	31
Engine and Tender, Automatic Brakes and Hand Brakes.												
Westinghouse	21	1052	50½	30	1700	59	22	1122	50¾	30½	2337	75
Eames	20½	827	44	29½	1475	55½	19¾	876	47	29½	2154	70½
Carpenter	20	955	56½	29½	1760	69	20	1142	58¼	30½	2222	73

For purpose of comparison it is of interest to add the record of emergency stops with 50 empty car trains equipped with Westinghouse brake, as made July 19th, 1886, at Burlington over same course:

First run	20½	354	16	40½	927	22¼	23	431	17½	43	1104	
Second run	23	424	17½	40	922	22½	23	427	17¼	43	1116	24½

H. H.

Cantilever Bridges.

On May 23d, 1887, an interesting lecture was delivered before the New York Academy of Sciences, by Professor W. P. Trowbridge, on the "Development of Bridge Construction." The lecture was accompanied by an extensive series of lantern-slide illustrations of the most noted bridges, from the old Roman arch to the structures now being erected. The development of the various types, from the earliest form

of the arch to the suspension bridge, and then the rigid truss was shown, and special attention was given to the cantilever type, that has lately come into popular notice.

It was in connection with the discussion of the cantilever that an interesting episode occurred which is well worthy of being put on record.

Allusion had been made in the lecture to the Niagara cantilever bridge as being the first application of this type on a large scale in the world, and the distinction was credited to the engineer, Mr. C. C. Schneider, of having been the first to work out the practical details, and erect this type of truss.

At the close of the lecture it was suggested to the chairman, by one of the audience, that Mr. Schneider was present, and might be induced to make some remarks upon the subject. A great deal of inducement proved necessary, but finally Mr. Schneider was brought to his feet amid general applause, and although his modesty prevented any detailed allusion to his work, it did not prevent his bearing testimony to the connection which the lecturer of the evening himself had with the introduction of the cantilever system in the United States, and he made the assertion that Professor Trowbridge was the first engineer to make a design for a cantilever bridge in this country.

This statement, coming from the engineer identified with the first large erection of the cantilever type, is of special interest, and cannot but be gratifying to Professor Trowbridge's numerous friends.

The design referred to was made some eighteen years ago for a bridge to cross the East River at Blackwell's Island, New York City. A company was formed, and advanced actively for some time, but finally the scheme was dropped.

Lately it has been resuscitated, and a cantilever design has been drawn up by Mr. Schneider with strong probability of ultimate construction.

Those who are interested in the history of the Blackwell's Island bridge, and the first designs made for it, will find the subject treated in an article in the *Engineering News*, vol. x., No. 52, p. 627.

* *

A Reminiscence.

"From the previous topic it was a natural step to the next one, viz., 'What are the best problems for students in mechanical engineering in the last year of their regular course?' One speaker thought they should be taught designing, and then the instructors should show them the faults of such designs. Evidently this person had no consideration for instructors. This process would be analogous to one in the writer's experience while a student at the School of Mines. It being desired to put sufficient ammonia into a solution to produce a reaction, the writer asked the instructor to smell it to see if there was sufficient. The instructor, who was a German, replied, 'I say every time, yes; I have not yet sold my nose to the School of Mines.' "—(From an article on the meeting of the American Society of Mechanical Engineers, in *Engineering*, London, by the New York correspondent.)

* *

Rainfall on the Land Surface of the Globe.

In the *Scottish Geographical Magazine* for February, 1887, Mr. John Murray has a paper on the rainfall of the globe and its relation to

rivers. He estimates the total land area at 55,700,000 square miles, and the total annual rainfall upon it at 29,350 cubic miles, making the average rainfall 33.5 inches.

About 11,500,000 square miles are inland drainage areas, such as the Caspian, the Sahara, and the like, and correspond very closely with the regions where the annual rainfall is less than 10 inches. These areas receive 2243 cubic miles of rain.

Of the remaining land, the Atlantic, or its tributary basins, drains 26,400,000 square miles to the extent of 15,788 cubic miles of rain, more than half the entire rainfall on the land, while the Pacific Ocean receives only 5007 cubic miles.

The Indian Ocean receives 4379 cubic miles, and the rain and snow falling on the Antarctic continent are estimated at 1688 cubic miles.

The supply from some of the principal rivers is thus stated:

The Amazon, with an area of 2,229,900 square miles, receives 2833 cubic miles of rain. The Congo comes next, with 1,540,800 square miles, and 1213 cubic miles; then the Nile, with an area of 1,293,050 square miles and a rainfall of 892 cubic miles; then the Mississippi, with 1,285,300 square miles, and 673 cubic miles of rain; and the La Plata, with 994,900 square miles of area, and a rainfall of 904 cubic miles.

In European rivers between a third and a fourth of the rainfall reaches the sea. The Mississippi discharges one-fourth of its rainfall into the Gulf of Mexico, and one-half of the rainfall on the basin of the Yukon finds its way to the ocean.—*Bulletin of Amer. Geographical Soc.*, vol. xix. No. 1.

BOOK REVIEWS.

THE MECHANICS OF MACHINERY. By Prof. Alex. B. W. Kennedy. London: Macmillan & Co. 1886. 644 pp. 12mo. $3.50.

Prof. Kennedy is Professor of Engineering and Mechanical Technology in University College, London. He has been also known for some time as the translator of Prof. Reuleaux's *Treatise on Kinematics*, and as an upholder of the methods of study which have been ascribed to that author. The present work is a presentation of the mechanics of constrained motion, as distinguished from the universal and general theorems of the science of mechanics, and by this limitation and concentration, a notable gain in directness and point is secured. In this respect the work will serve as a better and more intelligible guide than some of the recent French and German treatises which, while covering a greater area, perhaps, yet for that very reason bewilder the tyro in his effort to grasp the relations of principles, when those principles have been made clear to him. Prof. Kennedy adopts the principle of the instantaneous centre as the key to his presentation of the various mechanisms. He has made a noteworthy improvement upon the originators of this conception, by changing Rankin's term, instantaneous centre, into *virtual centre*. The change is of advantage from its brevity, and because the adjective, virtual, describes the junction and significance of the principle of the theorem in a manner more easy to grasp. In the discussion of the teeth of gear-wheels the principle is most simply and elegantly applied to bring out the theorems on which proper designs of profiles are based, and the demonstration is more limpid than the writer has ever seen in any previous treatise.

The book embraces twelve chapters. The first and second chapters define a machine, show why we are always faced with problems of constrained motion only in a working apparatus, and also define and discuss the usual kinds of motion. The principle of the instantaneous (or virtual) centre is presented, and it is shown clearly how the rolling of two curves which are loci of virtual centres for any motion can be made to reproduce that motion. Another notable improvement is the substitution of centrode for Prof. Reuleaux's less desirable term for the loci of virtual centres. The third, fourth and fifth chapters present constrained motion in usual mechanisms, using the Reuleaux conception of "pairs" for constraint, and show how the principle of virtual centres is utilized in study of their motions, and of their relative velocities. This is, of course, the geometrical side of the subject of mechanism, and abundant use is made of diagrams for illustration. The sixth and concluding chapter of the kinematic division of the subject treats of mechanisms which are not linkwork or obviously transposable into that form, and is devoted to a rational analysis of toothed gearing, without carrying it to a length which is unprofitable to a busy and practical student.

The second division of the book consists of six chapters also, and

covers the dynamics of mechanism. The subjects of velocities and acceleration, of force, mass, weight, and inertia of work and energy, are all clearly presented in their bearing upon machinery problems, and a full discussion of the static equilibrium conditions in elements and in composite mechanisms. Resistances form the topic of the ninth chapter, and technical examples are worked out. The discussion on governors is particularly clear and forcible. Kinetic equilibrium is treated also, and special attention given to the construction of velocity and acceleration diagrams on abscissas of spaces and of times. The practical use of these depending on the scales to be used in calculating them, special pains has been taken to bring these points out clearly. The tenth and eleventh chapters treat of miscellaneous mechanisms not covered in the more rigidly deductive parts, give some space to reduced mechanisms, to parallel motions and incomplete constraint of motions. The non-plane motions, such as some of the couplings and universal joints, are treated also by themselves. The parallel motion discussion cannot, of course, compare with Weisbach's full presentation, in the limits assigned to it.

The concluding chapter on friction in machines gains immensely in directness by neglecting entirely the laws of non-lubricated friction, and discussing only the conditions which prevail with smooth and unctuous surfaces of contact. The monumental experiments of Morin are supplemented by the recent investigations of Thurston and Tower having these very conditions in view. The author quotes Tower's formula

$$f = 20\, c \frac{\sqrt{v}}{P}$$

in which f is the friction factor or coefficient of friction, c is a constant for each type of oil (varying from 0.0014 for sperm oil to 0.0018 for mineral oil at journal pressures up to 300 or 450 pounds per inch of projected areas), and v is the peripheral velocity. P is the nominal pressure per square inch. This formula applies to perfect lubrication by the oil-bath system, and with a temperature of 90° Fahr., or blood-heat. Much more frequent reference is made in this part of the work to the results of Rankin's labors, and modern proportions and designs of footsteps and thrust-bearings are used for illustration.

The diagrams and pictures through the work are of a more satisfactory type to an Anglo-Saxon critic than those which have become an offence by repetition, and are so often to be met with in special treatises. Many of them are original with the author, and his use of the matter and diagrams of this book in the class-room before it appeared in print has been of great service to him and will prove equally useful to the student reader. As a whole, one rises from an examination of the book with a feeling of satisfaction that the author has had a distinct purpose before him, and has done his work well. F. R. H.

LESSONS IN ELEMENTARY PHYSICS. By Balfour Stewart, M.A., LL.D., F.R.S., and W. W. Haldane Gee, B. Sc. Vol. II. Electricity and Magnetism. 8vo. 497 pp. Macmillan & Co. 1887. $2.25.

The second volume of Messrs. Stewart and Gee's admirable treatise on elementary practical physics deals with the subject under considera-

tion with the same thoroughness that distinguishes the first volume of the series. It is, as it claims to be, a thoroughly practical work. A very good plan is followed, of sub-dividing the subject into a series of lessons, each dealing with a particular exercise, for which explicit directions are given, neglecting no details which are necessary to make the operations clear. Directions are given for the construction of almost all the apparatuses needed in the experiments described, and considerable ingenuity is displayed in utilizing the simplest material, such as can be readily obtained by any student. The first three chapters are introductory, dealing only with the elementary principles of the subject. The remaining chapters are devoted to a description of the various methods of measurement in electricity and magnetism. Chapter IV. on the measurement of resistance is very complete, and contains careful descriptions of most of the important methods in practical use to-day. Chapter V. very fully explains the various uses of the tangent compass. In Chapter VI. directions are given for the manipulation of instruments, such as are made use of in the great magnetic observatory at Kew, England. Chapters VIII. and IX. deal respectively with the use of the condenser and the electrometer. In the Appendix under the title of the "Wheatstone net" is given a discussion of Kirchhoff's laws, which, for clearness and completeness excels anything to be found in any other text-book which has come under our observation. These important laws are too little understood in their practical application to problems in electrical measurement involving the use of Wheatstone's bridge, and Messrs. Stewart and Gee have performed an important service to students in electricity by the clear way in which they explain their application. Only one objection can be made to the book as a whole, and that is the lack of an index. One general index for the three volumes does not meet the requirements; as each volume is complete in itself in all other respects, there seems to be no good reason for this omission. We commend this book to all students of electricity as one well worthy of careful perusal. W. W. S.

ERRATUM.—For the initials J. K. R., subscribed to review of "Elementary Treatise on Determinants," in the last number, read T. S. F.

OFFICERS AND MEMBERS OF THE ALUMNI ASSOCIATION AND ALL OTHER GRADUATES OF THE SCHOOL OF MINES.

President: Frederick Augustus Schermerhorn, E.M., '68.
First Vice-President: Walter Bourchier Devereux, E.M., '78.
Second Vice-President: John Cooper F. Randolph, E.M., '69.
Treasurer: John Krom Rees, E.M., '75.
Secretary: Pierre de Peyster Ricketts, Ph.D., '71.
Assistant Secretary: Thomas Beale Stearns, E.M., '81.

Managers.

'68. Frederick A. Schermerhorn, E.M.
'69. John Cooper F. Randolph, E.M.
'71. Pierre de Peyster Ricketts, Ph.D.
'75. John Krom Rees, E.M.
'76. Frederick Remsen Hutton, Ph.D.
'76. Edward Gurley Love, Ph.D.
'78. Willard Parker Butler, E.M.
'80. Alfred Lockwood Beebe, Ph.B.
'80. Wheaton Bradish Kunhardt, E.M.
'82. Alfred Joseph Moses, E.M.
'82. William Barclay Parsons, E.M.
'84. William Fellowes Morgan, E.M.

HONORARY MEMBERS.

C. R. Agnew, M.D., Trustee of Columbia College. Address, 266 Madison Avenue, New York City.

F. A. P. Barnard, S.T.D., LL.D., President of Columbia College. Address, Columbia College, New York City.

Charles F. Chandler, Ph.D., Professor of Chemistry, School of Mines, Columbia College. Address, 51 East Fifty-fourth Street, New York City.

Thomas Egleston, E.M., Ph.D., Professor of Mineralogy and Metallurgy, School of Mines, Columbia College. Address, 35 West Washington Square, New York City.

Hamilton Fish, LL.D., Trustee of Columbia College. Address, 251 East Seventeenth Street, New York City.

George M. Miller, Montmoor, Rockland County, N. Y.

J. S. Newberry, M.D., LL.D., Professor of Geology and Palæontology, School of Mines, Columbia College. Address, School of Mines, New York City.

W. G. Peck, Ph.D., LL.D., Professor of Mechanics, School of Mines, Columbia College. Address, Greenwich, Connecticut.

O. N. Rood, A.M., Professor of Physics, Columbia College. Address, Columbia College, New York City.

L. M. Rutherfurd, 175 Second Avenue, New York City.

W. P. Trowbridge, Ph.D., LL.D., Professor of Engineering, School of Mines, Columbia College. Address, School of Mines, New York City.

J. H. Van Amringe, A.M., Ph.D., Professor of Mathematics, School of Mines, Columbia College. Address, 51 East Forty-fourth Street, New York City.

William R. Ware, B.S., Professor of Architecture, School of Mines, Columbia College. Address, 448 Madison Avenue, New York City.

REGULAR AND ASSOCIATE MEMBERS AND ALL OTHER GRADUATES.

(*Graduates not Members in Italics.*)

1867.

John Magnus Adams, A.M., E.M., Mining and Mechanical Engineer, Agent for Frue Vanner, etc., 109 California Street, Room 7, San Francisco, Cal.

Samuel Willard Bridgham, E.M., 49 West Twenty-third Street, New York City.

Francis Gordon Brown, E.M., Merchant, 116 East Twenty-seventh Street, New York City.

Edward Steele Bronson, A.M., E.M. Residence, 39 Garden Place, Brooklyn, N. Y.

John Adams Church, E.M., Ph.D., Mining Engineer, Tarrytown, Westchester Co., N. Y.

Henry Bedinger Cornwall, A.M., E.M., Professor of Analytical Chemistry and Mineralogy, College of New Jersey, Princeton, N. J.

Edward Everett Giddings, E.M., Commission Merchant, 413 Royal Insurance Building, Chicago, Ill.

Charles King Gracie, A.M., E.M.

Albert Ward Hale, A.M., E.M., Civil and Mining Engineer, 1 Broadway, Room 206, New York City.

George Edward Harding, Civil Engineer, 40 Exchange Place, New York City.

Thomas Hayes Harmer, A.B., E.M., 113 East Thirty-seventh Street, New York City.

Frederic Milton Heath, E.M., Potsdam, St. Lawrence County, N. Y.

David Van Lennep, E.M., Auburn, Placer County, Cal.

William Wey Tuttle, E.M., 208 College Street, Springfield, Mo.

1868.

Augustus Porter Barnard, E.M., 28 West 20th Street, New York City.

George Strong Baxter, A.M., Mining and Civil Engineer, Northern Pacific Railroad, St. Paul, Minn.

James Petigru Carson, E.M. Address, 16 Exchange Place, New York City.

Albert Huntington Chester, A.M., E.M., Ph.D., Professor of Chemistry and Mineralogy, Hamilton College, Clinton, Oneida County, N.Y.

George Hampton Coursen, E.M., C.E., 307 Greenwich Street, New York City.

George Jarvis Geer, Jr., E.M., Merchant, 453 Broome Street, New York City.

George Byron Hanna, A.B., E.M., Melter, U.S. Assay Office, Charlotte, N. C.

Archibald MacMartin, A.M., E.M., Died in New York City, May 7th, 1881.

†D. Ernest Melliss, Ph.D., San José de las Bocas Sinaloa, Mexico.

Edward Stewart Moffat, A.M., E.M., Assistant General Manager, Lackawanna Iron and Coal Company, Scranton, Pa.

George Howland Parsons, E.M., Superintendent of Land Improvement Company, Colorado Springs, Col.

---

† Associate Member. Not eligible for office.

†Joseph Pope Pennington, A.M., 1201 Fairmont Avenue, Elizabeth, New Jersey; care of W. V. McCracken & Co., Railroad Builders, 42 Wall Street, New York City.

William Pistor, E.M., Architect, 35 Broad Street, New York City. Residence, 13 East Thirty-seventh Street, New York City.

Charles Slason Platt, E.M., Assayer, 4 Liberty Place, New York City.

Kenneth Robertson, E.M., Secaucus Iron Co., Secaucus, Hudson County, N. J.

Albert P. Schack, E.M. Address, 11 West Eighteenth Street, New York City.

Frederick Augustus Schermerhorn, E.M., Trustee of Columbia College. Address, 61 University Place, New York City.

Lenox Smith, A.B., E.M., Trustee of Columbia College, 3 Broad Street, New York City.

William Allan Smith, E.M., Consulting Engineer, 16 Exchange Place, New York City.

Frederick Stallnecht, E.M., Editor, 11 Bond Street, New York City.

William Henry Van Arsdale, A.M., E.M., Vice-President Chicago & Aurora Smelting and Refining Company, Aurora, Ill. Office, 177 Dearborn Street, Chicago, Ill.

Moses Dillon Wheeler, A.B., E.M., P.O. Box 539, Stapleton, Richmond County, Staten Island, N.Y.

1869.

Thomas Monahan Blossom, A.B., A.M., E.M., Died in California, October, 1876.

Frederick Bruckman, E.M., Excelsior Iron Works, 128 West Fifth Street, Leadville, Col.

Alonzo Clarence Campbell, E.M., Chemist and Mining Engineer, 227 Shelby Avenue, Nashville, Tenn.

†Augustus Flood Delafield, Ph.D., University Club, New York City; also Noroton, Fairfield County, Conn.

William Augustus Hooker, A.M., E.M.; care Hooker & Lawrence, 145 Broadway, New York City.

†Chester Huntington, P.O. Box 1780, New York City.

Roland Duer Irving, A.M., E.M., Ph.D., Professor of Geology and Mineralogy in the University of Wisconsin, Madison, Wis., and United States Geologist in charge of Survey of Crystalline Rocks of the Northwestern States.

Walter Proctor Jenney, E.M., Ph.D., Consulting Engineer and Geologist. Address, care of S. Jenney & Son, 128 Pearl Street, New York City.

Henry Smith Munroe, E.M , Ph.D., Adjunct Professor of Surveying and Practical Mining, School of Mines, Columbia College, New York City.

Lionel Robert Nettre, E.M., Grillparzer Strasse 11, Vienna, Austria.

Henry Newton, A.B., E.M., Ph.D., Died in Deadwood City, Dakota Ter., August 5th, 1877.

William Bleecker Potter, A.M., E.M., Professor of Mining and Metallurgy, Washington University, St. Louis, Mo.

John Cooper F. Randolph, A.M., E.M., Consulting Mining Engineer, 35 Broadway, New York City.

---

† Associate member. Not eligible for office.

1870.

Ogden Haight, E.M., Stock Broker, 38 Broadway, New York City.

William Halsey Ingersoll, A.M., E.M., LL.B., United States Stamping Company, Portland, Conn.

John Augustus Knapp, A.M., E.M., Chicago and Aurora Smelting and Refining Company, Office 177 Dearborn Street, Chicago, Ill.

John Leo Lilienthal, E.M., P. O. Box 2258, San Francisco, Cal.

Stuart Lindsley, E.M. Address, Orange, N. J.

Edward Moore Parrott, E.M., Parrott Iron Company. Post-office address, Greenwood Iron Works, Orange County, N. Y.

Richard Henry Terhune, E.M., Superintendent of the Hanover Smelting Works, Salt Lake City, Utah.

Theodore Francis Van Wagenen, E.M., Consulting Engineer and Secretary Venture Blasting Powder Company, 1648 Lawrence Street, Denver, Col.

Elwyn Waller, A.M., E.M., Ph.D., Professor of Analytical Chemistry, School of Mines, Columbia College, New York City.

1871.

William E. S. Fales, A.B., E.M., LL.B., Counsellor-at-Law, 189 Montague Street, Brooklyn, N. Y.

Samuel Anthony Goldschmidt, A.B., E.M., Ph.D., Manufacturing Chemist, Columbia Chemical Works, 20 to 30 Jay Street, Brooklyn, N. Y.

John Gordon, Jr., E.M., Merchant, 62 Rua Sas Pedro, Rio Janeiro, Brazil.

Pierre de Peyster Ricketts, E.M., Ph.D., Professor of Assaying, School of Mines, Columbia College, New York City.

George Washington Riggs, Ph.B., Analytical Chemist, 114 Pearl Street, New York City.

Gracie Sayre Roberts, E.M., C.E., Topographical Engineer, Department of City Works, Brooklyn, L. I. Address, Rockville Centre, Queens County, N. Y.

Richard Spotswood Robertson, Jr., E.M., Jackson, Minn.

1872.

Peter Townsend Austen, Ph.D., F.C.S., Professor of General and Applied Chemistry, Rutgers College, New Brunswick, N. J.

Frank B. Jenney, E.M. Died in Trinidad in 1876.

Frederick H. McDowell, E.M., Beckett & McDowell, 120 Liberty Street, New York City.

Thomas O'Connor Sloane, A.M., E.M., Ph.D., Chemist, 119 Pearl Street, New York City.

Arthur Frederic Wendt, E.M., C.E., Ph.D., care of Charles E. Wendt, 80 Wall Street, New York City.

1873.

Frederick A. Canfield, A.M., E.M., Royal Potosi Silver Mining Company (Limited), Potosi, Bolivia. Address, Dover, N. J.

Charles Adams Colton, E.M., Director Newark Technical School. Address, 21 West Park Street, Newark, N. J.

Henry Augustus Mott, Jr., E.M., Ph.D., Mining Engineer and Analytical Chemist, 61 Broadway, Room 56, New York City.

Henry Walter Webb, E.M. Residence, 14 West Thirty-eighth Street, New York City.

John Townsend Williams, E.M., Ph.B., Williams, Clark & Co., Cotton Exchange Building, Hanover Square, New York City.

1874.

Charles Sumner Allen, Ph.B., M.D., Practicing Physician, 109 East Eighty-sixth Street, New York City.

John Gedney Mott Cameron, E.M., C.E., Assayer, Spears & Howard. Address, Fifty-fifth Street and Madison Avenue, New York City.

William de Liesseline Benedict, E.M., Benedict & Cole, 32 Liberty Street, New York City.

†Albert Reid Ledoux, M.S., Ph.D., Chemist, 10 Cedar Street, New York City.

Samuel Morris Lillie, E.M., Box 49, Philadelphia, Pa.

George Murray, E.M., Superintendent Horn Silver Smelting Works, Franklin, Utah. Address, 235 West Twenty-third Street, New York City.

Eben Erskine Olcott, E.M., Mining and Metallurgical Engineer, 10 Cedar Street, New York City.

Benjamin Franklin Rees, E.M., Merchant, 17 and 19 Ferry Street, New York City.

Francis Bell Forsyth Rhodes, E.M., Chicago and Aurora Smelting and Refining Company, Office, 177 Dearborn Street, Chicago, Ill.

Frederick Harrison Williams, E.M. Address, Box 502, Orange, N. J.

1875.

Magnus C. Ihlseng, E.M., C.E., Ph.D., Professor of Engineering, State School of Mines, Golden, Col.

Malvern Wells Iles, Ph.D., Superintendent of Holden Smelting Company, Denver, Col.

Charles Edward Jackson, C.E., Assistant Engineer, Brooklyn Elevated Railroad Company. Address, 122 East Nineteenth Street, New York City.

Douglas Arad Joy, E.M., Assistant in Chemistry, University of Michigan, Ann Arbor, Mich. Address, Marshall, Mich.

Robert Schuyler Lamson, C.E. Died in Darbour, Upper Egypt, in 1876.

Harry Wenman Leavens, E.M., Agent Kansas City Smelting and Refining Company, P. O. Box 543, Salt Lake City, Utah.

Arthur Macy, Ph.B., C.E., Superintendent Silver King Mining Company, Silver King, Pinal County, Arizona.

William Skaats Noyes, E.M., Superintendent of Cibola Creek Mill and Mining Company, Shafter, Presidio County, Texas.

Philip Charles Pfister, E.M., Black & Pfister, 142 Maiden Lane, New York City.

Bayard Taylor Putnam, E.M. Died.

John Krom Rees, A.M., E.M., Professor of Geodesy and Practical Astronomy, and Director of the Observatory, Columbia College, New York City.

Charles M. Rolker, E.M., Mining Engineer, 18 Broadway, New York City.

---

† Associate member. Not eligible for office.

Samuel Howland Russell, E.M., 39 East Eighteenth Street, New York City. Resigned.

Hunter Stewart, E.M., Civil Engineer. Address unknown.

Milton Strong Thompson, Ph.B., Chemist, Chrolithion Manufacturing Company, Newburyport, Mass.

John Henry Tucker, Ph.B., Superintending Chemist, Philadelphia Sugar Refinery, 225 Church Street, Philadelphia, Pa.

James Simpson Chester Wells, Ph.D., Instructor in Analytical Chemistry, School of Mines, Columbia College, New York City.

Franklin Vanderpoel, E.M., Chemist Celluloid Manufacturing Company, Newark, N. J.

Edwin Atwater Wetmore, E.M., care of E. A. Wetmore & Co., Iron Merchants, Marquette, Mich.

Albert Allen Wright, A.M., Ph.B., Professor of Geology and Natural History, Oberlin College, Oberlin, O.

1876.

Thomas Septimus Austin, E.M., Superintendent Germania Smelting Works, Salt Lake City, Utah.

Frederick Everett Bruen, E.M., C.E. Died in Leadville, Col., November 8th, 1884.

George Rockwell Cornwall, E.M., C.E., Mining Engineer, Irwin, Gunnison County, Col.

Francis Sanderson Craven, E.M., C.E., Superintendent of Bear Gulch Placer Company, Gardiner, Montana.

Edmund Hyatt Garrison, E.M., C.E., Assistant Treasurer, Central Park, N. & E. R.

Herbert Carrington Foote, C.E., Professor of Chemistry, Central High School, and Homœopathic Hospital College, Cleveland, O. Address, 37 Arlington Court, Cleveland, O.

Louis Pope Gratacap, Ph.B., M.A., Curator American Museum of Natural History, Central Park, New York City.

Robert William Hall, E.M., American Gas, Fuel and Light Company, 33 Broadway, Room 17, New York. Residence, 3 West Fifty-sixth Street, New York City.

Schuyler Hamilton, Jr., A.M., E.M., care of William Pistor, Architect, 35 Broad Street, New York City.

Francis Newberry Holbrook, C.E., Mining and Constructing Engineer, care of Holbrook & Foucar, El Paso, Texas. Address, P. O. Box 1624, New York City.

Walter Lowrie Hoyt, E.M., Superintendent St. Louis S. and R. Co., 417 Pine Street, St. Louis, Mo.

Frederick Furneaux Hunt, E.M., C.E., Box 335, Quebec, Canada.

Frederick Remsen Hutton, A.M., E.M., C.E., Ph.D., Adjunct Professor in Mechanical Engineering, School of Mines, Columbia College. Residence, 6 West Thirty-third Street, New York City.

Charles King, Ph.B.

Nathaniel Wright Lord, E.M., Professor of Mining and Metallurgy, Ohio State University, Columbus, O.

Edward Gurley Love, A.M., Ph.D., Gas Examiner, Dept. of Public Works; Examiner in Chemistry, College of Physicians and Surgeons. Address 69 East Fifty-fourth Street, New York City.

John Holme Maghee, A.M., C.E., 16 East Fifty-fourth Street, New York City.

Henry Francis Moorewood, E.M., Importer, 34 South Street, New York City.

James William O'Grady, E.M., C.E., Horne Street opposite Villa Place, Morrisania, N. Y.

James Fitz Randolph, B.S., E.M., Communipaw Coal Company, 111 Broadway, Room 40, New York City.

William Coleman Ross, E.M., C.E., Silver City, Grant County, New Mexico.

Albert Francis Schneider, E.M., C.E., Superintendent Kansas City Smelting and Refining Company, Argentine, Kansas. 721 Tracey Avenue, Kansas City, Mo.

George Cyrus Tilden, C.E., Hildebrand & Tilden, 247½ Seventeenth Street, Denver, Col.

Elbert Chaplin Van Blarcom, C.E. Address, P. O. Box 2085, San Francisco, Cal.

Augustus Clark Walbridge, E.M., C.E., Builder, 120 Broadway, Room 21, New York City.

James Robert Wardlaw, C.E., 39 Nassau Street, Room 31, New York City.

1877.

Louis de Souza Barros, C.E., E.M., San Paulo, Brazil.

†Carl Barus. Ph.D., Physicist, United States Geological Survey, National Museum, Washington, D. C.

James Thom Beard, E.M., C.E., Ottumwa, Iowa.

Edward Behr, C.E., Behr Bros. & Co., 15 East Fourteenth Street, New York City.

Charles Ramsay Buckley, A.M., E.M. Address, 35 Broadway, Room 69, New York City.

Linus Bertram Cady. E.M., C.E. Address, 234 West Thirty-eighth Street, New York City.

Augustus Cass Canfield, E.M., 60 West Fifty-fourth Street, New York City.

John Brifton Caldwell, C.E., 6 East Forty-ninth Street, New York City.

Henry Gilbert Clarke, E.M., C.E. Died in Aurora, Nevada, August 22d, 1881.

Charles Edwards Colby, E.M., C.E., Instructor in Organic Chemistry, School of Mines, Columbia College, New York City.

Charles Lewis Constant, E.M., C.E., 608 Lexington Avenue, New York City.

George Birdsall Cornell, E.M., C.E., Chief Engineer Brooklyn Elevated Railroad, 51 Fulton Street, Brooklyn, N. Y. Residence, 46 West Forty-eighth Street, New York City.

Frederick William Floyd, E.M., C.E., 539 West Twentieth Street, New York City. Residence, 28 West Sixty-first Street.

Frank Stuart Hellebergs, C.E. Died in Leadville, Col., October 4th, 1883.

Walter Edwards Hildreth, E.M., C.E., Consulting Engineer, 52 Broadway, Room 48, New York City.

Axel Olaf Ihlseng, B.S., E M., C.E., 151 East Thirty-third Street, New York City.

José Nabor Pacheco Jordao, C.E., E.M., Ph.B., Paulista Railroad, San Paulo, Brazil.

William Kelly, A.B., E.M., Riddlesburg, Bedford County, Pa.

James Buckton Mackintosh, E.M., C.E., Instructor in Qualitative Analysis, Lehigh University, South Bethlehem, Pa.

†Edward Ward Martin, New York Board of Health. Address, School of Mines, New York City.

John Glenville Murphy, E.M., C.E., Middletown, Middlesex County, Conn.

† Associate member. Not eligible for office.

Ralph Nichols, E.M., C.E., Superintendent Viola Mining and Smelting Company, Nichola, Leenhi County, Idaho. Winter address, 26 Broad Street, New York City.

Dudley Hiram Norris, E.M., Lawyer, Mills Building, 35 Wall Street, New York City. Residence, 112 Lafayette Avenue, Brooklyn, N. Y.

James Robert Priest, E.M., C.E. Died in Greenville, Liberia, Africa, in 1880.

William Helsham Radford, E.M., North Bloomfield, Nevada County, Cal.

Sylvanus Albert Reed, A.M., E.M., Ph.D., 6 East Fifty-third Street. Superintendent of Inspection Commonwealth Insurance Company, 29 Wall Street, New York City.

Charles Lewis Rogers, E.M., C.E., Gilbert Avenue, Cincinnati, O.

Edward Eugene Sage, C.E., Assistant Assayer, United States Assay Office, New York City.

William Henry Smeaton, E.M., C.E., 316 West Twentieth Street, New York City.

Roland Mulville Smythe, E.M., C.E., 539 Henry Street, Brooklyn, N. Y.

Arthur Thacher, E.M., C.E., 61 Broadway, Room 25, New York City.

Robert Ward Van Boskerck, C.E., Artist. Studio, Sherwood Building, 58 West Fifty-seventh Street, New York City.

Cornelius Reed Waterbury, C.E., Attorney and Counsellor-at-Law, 115 Broadway. Residence, One Hundred and Twenty-fifth Street and Eighth Avenue, New York City.

1878.

William James Adams, A.M., E.M., Murphy's, Calaveras County, Cal.

Marcus Benjamin, Ph.B., F.C.S., Consulting Chemist. Residence, 43 East Sixty-seventh Street, New York City.

Charles Edward Blydenburgh, A.M., E.M., Mining Expert and Prospector. Box 189, Rawlins, Wyoming.

Robert Elmer Booraem, E.M., General Manager Blue Bird Mining Company, Butte City, Montana.

George Charles Brinkerhoff, E.M. Address, Apartado 183, Matanzas, Cuba.

Willard Parker Butler, E.M., LL.B., Counsellor-at-Law and Solicitor of Patents, 59 Wall Street, New York City.

Alexander Ramsay Cushman, Ph.D., 128 East Sixteenth Street, New York City.

John Woodbridge Davis, C.E., Ph.D., Principal of Woodbridge School, 32 East Forty-fifth Street, New York City.

Walter Bourchier Devereux, A.M., E.M., Manager Aspen Smelting Company, Aspen, Col.

Orrien Pinkerton Downing, Ph.B., San Leandro, Cal.

Isaac Wyman Drummond, E.M., Ph.D., Chemist, F. W. Devoe & Co., Corner Fulton and William Streets, New York City.

Walter Graeme Elliott, E.M., C.E., Ph.D., Consulting Sanitary Engineer, University Club, New York City.

Anton Fernekes, E.M. Died in Milwaukee, Wis., March 13, 1884.

Harry Leopold Haas, Ph.B., Zucker & Levett Chemical Co., 540 West Sixteenth Street, New York City.

Yothinosuke Hasegawa, E.M., Ph.D., Imperial Mint, Osaka, Japan.

Henry Albert Hodges, E.M. Died in New York City, July 4, 1883.

Edward Henry Holden, C.E., Surveyor and Civil Engineer, One Hundred and Sixty-ninth Street and Boston Avenue, Morrisania, N. Y.

William Hollis, C.E., P.O. Box 109, Eagle Pass, Texas.

Elias Mattison Johnson, E.M., Ph.B., care of I. G. Johnson & Co., Spuyten Duyvil, N. Y.

Gilbert Henry Johnson, Ph.B., Chemist, I. G. Johnson & Co., Spuyten Duyvil, N. Y.

Corydon Powell Karr, Ph.B., Consulting Architect, Room 215 Stewart Building, Broadway and Chambers Street, New York City.

Benjamin Bowden Lawrence, E.M., 216 East 18th Street; Hooker & Lawrence, 145 Broadway, New York City.

Frank Lyman, A.M., E M., Pig Iron, 130 Water Street, New York City. Residence 47 Remsen Street, Brooklyn, N. Y.

Nawokichi Matsui, Ph.D., Instructor in Qualitative Analysis, University of Tokio, Tokio, Japan.

Edward Austin McCulloh, Ph.B. Address P.O. Box 2346, New York City.

George Barrow Moorewood, E.M., Ph.D., Tea Importer, 121 Front Street, New York City.

Gouverneur William Morris, E.M., Myers, Rutherford & Co., 58 Wall Street, New York City. Address 11 Waverly place.

Charles Edward Munsell, Ph.D., Assistant Chemist, F. W. Devoe & Co., 100 Horatio Street, New York City. Address, Rye, N. Y.

Henry Morgan Murphy, E.M., Murphy & Co., 231 Broadway, New York City.

K. Nambu, Imperial ——, Tokio, Japan.

Spencer Baird Newberry, E.M., Ph.D., Professor of Chemistry, Agricultural Department, Cornell University, Ithaca, N. Y.

James Atkins Noyes, Ph.B., A.B.; with J. L. Bremer & Co., Dry Goods, 62 Leonard Street, New York City. Address, 155 Remsen Street, Brooklyn, N. Y.

Kiugo Okuma, E.M., Senmon Gakko Waseda, Tokio, Japan.

Owen Frederick Olmstead, C.E., Died in Albany, N. Y., November 21, 1881.

Frederick Nash Owen, E.M., Civil and Sanitary Engineer, 13 William Street, New York. Residence, Flushing, Queens Co., N. Y.

Cortlandt Edward Palmer, E.M., Hewett Sampling Works, Aspen, Col.

Richard Alexander Parker, C.E., Sergeant Drill Co., 16 Dey Street, New York City.

Vincent Felix Pazos, E.M., Lima, Peru.

Nelson W. Perry E.M., 238 Auburn Avenue, Cincinnati, O.

William Strieby, A.B., E.M., Professor of Metallurgy and Assaying, Colorado College, Colorado Springs, Col.

Bailey Willis, E.M., C E., Geologist, United States Geological Survey, Washington, D.C. Residence, 1823 Eighth Street, N. W.

1879.

Robert Bolton, Ph.B., Rock Hill Iron and Coal Co., Orbisonia, Huntingdon County, Pa.

Nathaniel Lord Britton, E.M., Ph.D., Instructor in Botany, School of Mines, Columbia College, New York City.

Leo George Cloud, A.B., E.M., 216 Monmouth Street, Newport, Campbell County, Ky.

Harry Clay Cornwall, E.M., 204 Columbia Heights, Brooklyn, N. Y.

Louis Phillipe de Luze, C.E., New Rochelle, West Chester County, N. Y.

George Spencer Eastwick, C.E., Manager Louisiana Sugar Refinery, New Orleans, La.

Louis Francis Haffen A.M., C.E., Brewer, 152d Street and Courtland Avenue, New York City.

Charles Sumner Harker, E.M., Bodie Tunnel Company, Bodie, Cal.

Nathaniel Hathaway, Ph. B., Analytical Chemist, New Bedford, Mass.

Herman Hollerith, E. M., Solicitor of Patents, 617 Seventh Street, Washington, D.C., and Room 86 Kemble Building, 25 Whitehall st, New York City.

Charles Arthur Hollick, Ph.B., Sanitary Inspector New York Board of Health, Box 105, New Brighton, S. I.

Isaac Bradley Johnson, E.M., Spuyten Duyvil, N. Y.

Robert Andrew Johnston, C.E., Assistant Sanitary Engineer, New York Board of Health. Address, Scarsdale, N. Y.

Edward Cabet Koch, E.M., Little Annie Gold Mining Company, Summitville, Rio Grande County, Col. City Address, 160 East Fifty-sixth Street, New York City.

Thomas Haight Leggett, Jr., E.M., Mining Superintendent and Engineer, Rosario Mining Company, San Juancito, Tegucigalpa, Honduras, Central America.

Edwin Ludlow, E.M., Superintendent Mineral R.R. & Mining Company, Shamokin, Pa.

Charles Wells Marsh, Ph.D., Instructor in Organic Chemistry, Lehigh University, South Bethlehem, Pa.

Theophilus Smith Mathis, E.M., Engineer of Mines and Deputy United States Mineral Surveyor, Telluride, San Miguel County, Col.

Ralph Edward Mayer, C.E., Assistant in Drawing, School of Mines, Columbia College, New York City.

Hubert John Merwin, E.M., Civil Engineer, Lawrence (?) House, Knoxville, Tenn.

George Fanshaw Milliken, E.M., 70 Broadway, New York City

Otis Mortimer Munroe, Ph.B., Banker, De Soto, Jefferson County, Mo.

Knight Neftel, C.E., Ph.D., care of Neftel & Oothout, 41 Liberty Street, New York City.

James Nesmith, E.M., 256 Henry Street, Brooklyn, N. Y.

Charles Milton Noble, E.M., General Foreman, Woodstock Iron Works, Anniston, Ala.

William Bell Stephen Reed, E.M., 171 St. Mark's Avenue, Brooklyn, L. I.

Robert Dunn Rhodes, E.M., Bullionville Smelting Company, Bullionville, Lincoln County, Nevada.

Francis Morris Rutherford, E.M., Assistant Supervisor Pennsylvania Railroad, Bordentown, N. J.

Gardner Hutchinson Sheldon, E.M., Corralitos, Chihuahua, Mexico.

Henry Fowler Starr, Ph. B., Chemist, Newark Steel Works. Address 38 Orleans Street, Newark, N. J.

Francis Barretto Stewart, Ph.B., Died in Harlem, N. Y., August, 1879.

George Cameron Stone, Ph.B., Chemist New Jersey Zinc and Iron Company, Newark, N. J. Address, 146 Lexington Avenue, New York City.

John Richard Suydam, Jr., E.M., 43 East Twenty-second Street, New York City.

Granville Whittlesey Williams, E.M., C.E., 215 Genesee Street, Utica, N. Y.

1880.

Alfred Lockwood Beebe, Ph.B., Chemist, with Prof. Ricketts, School of Mines, Columbia College. Residence, 3 East Forty-seventh Street, New York City.

Frank Parkinson Benjamin, E. Address, 44 New Street, New York City.

Frederick Dennison Browning, E.M. Died at Colorado Springs, Col.

†John H. Brower Browning, M.D., 106 East 74th Street, New York City.

William Frederic Brugman, Ph.B., Head Chemist, Scranton Steel Company, Scranton, Pa.

Nathaniel Butler, E.M., care H. & N. Russell, 32 Barclay Street, New York City.

Alfred Daniell Churchill, A.M., M.S., E.M., Ph.D., The Consolidated Ten Mile Milling & Reduction Company, 15 Whitehall Street, Room 136, New York City.

Edwin Perry Clark, E.M., Superintendent Title Guarantee and Trust Company, 38 Park Row, New York City. Residence, 435 Fifth Street, Brooklyn, N. Y.

William Elliott, Ph.B., Chemist, Elliott & Mattison, 197 Pearl Street, New York City.

Louis George Engel, E.M., 238 Clermont Avenue, Brooklyn, N. Y.

Robert Otto Francke, C.E., care J. J. Francke, 120 Front Street, New York City.

Herman Garlichs, E.M., Chicago & Aurora Smelting and Refining Company, North Aurora, Ill.

Wilkins Updike Greene, Ph.B., 15 Cranberry Street, Brooklyn, N. Y.

James Leal Greenleaf, C.E., Instructor in Engineering and Drawing, School of Mines, Columbia College, New York City.

Albert Peter Hallock, Ph.D., Chemist, New York Gaslight Company, Twenty-first Street and Avenue A., New York City. Residence, 203 Rutledge Street, Brooklyn, N. Y.

Henry Harmon Hendricks, Ph.B., Hendricks Bros., 49 Cliff Street, New York City.

Louis Mosher Hooper, C.E., Sanitary Department, New York Board of Health. Residence, 5 West Forty-second Street, New York City.

Theodore M. Hopke, Ph.B., Linden Steel Co., Pittsburgh, Pa.

Edward Henry Hudson, C.E. Address unknown.

Frank Klepetko E.M., Mining Engineer to Osceola and Tamarack Mining Company. Address, Opechee P. O., Houghton County, Mich.

Wheaton Bradish Kunhardt, E.M., Engineer with the Bower-Barff Rustless Iron Company of New York. Address, care of Prof. Maynard, 35 Broadway, New York City.

Joseph Godley Mattison, Ph.B., Chemist, Elliott & Mattison, 197 Pearl Street, New York City.

Charles August Meissner, Ph.B., Superintendent Stirling Iron and Railway Company Furnaces, Stirlington, N. J.

James Haviland Merritt, Ph.B., Chemist, 117 York Street, Brooklyn. Residence, 35 Willow Street, Brooklyn, N.Y.

Juan Adalberto Navarro, C.E., Inspector del Ferro Carrillo, Interoceanico, Apartado, 213, Mexico City, Mexico.

Andrew McClean Parker, E.M., Civil Engineer, 59 and 61 Wall Street, New York City.

John Randolph Parks, E.M., 172 Rutledge Street, Brooklyn, N. Y.

---

† Associate member. Not eligible for office.

Henry Alvord Robinson, Ph.B., Lawyer, with Robinson, Scribner & Bright, 150 Broadway, New York City. Residence, 19 East Sixty-ninth Street, New York City.

Ferdinand Ruttmann, Jr., E.M., 35 Liberty Street, New York City.

George Singer, Jr., E.M. Address, Wilkinsburg, Allegheny County, Pa.

George Harton Singer, E.M., Singer, Nimmick & Co., Pittsburgh, Pa.

Wallace Augustus Smalley. Died July 25th, 1886, at Silver City, New Mexico.

Maxwell Smith, C.E., Resident Engineer, Chicago, Milwaukee & St. Paul R.R., Mapleton, Iowa.

Theodore Tonnelé, Ph.B., with W. D. Wood & Co., McKeesport, Pa. City Address, 48 East Sixty-eighth Street, New York City.

Charles Herbert Torrey, Ph.B., care of Dubois Manufacturing Co., 15 Britannia Street, London, W. C., England.

Joseph Walker, Jr., C.E., 289 Fifth Avenue, New York City.

Herbert Allen Wheeler, E.M., Instructor, Washington University, St. Louis, Mo.

1881.

Charles Alfred Andresen, E.M., with Pickard & Andresen, 8 Gold Street, New York City.

Frederic Theodor Aschman, Ph.B., Analytical Chemist, Sharon, Mercer County, Pa.

Charles Popham Bleecker, E.M., 48 South Street, New York City.

Victor Manuel Braschi, E.M., Ph.B., C.E., care of Rand Drill Co., 23 Park Place, New York City.

Edward Renshaw Bush, E.M. Address, care J. Adriance Bush, 10 Wall Street, New York City.

Philip Edward Chazal, A.B., E.M., State Chemist, Columbus, S.C.

Albert Ladd Colby, Ph.B., Head Chemist, Bethlehem Iron Co. Address, Eagle Hotel, Bethlehem, Pa.

Charles Gordon Curtis, C.E., Curtis & Crocker, 140 Nassau Street, New York City.

Edward Morehouse Douglas, C.E., Topographer, U. S. Geological Survey, Washington, D. C.

Edward Kellogg Dunham, Ph.B., Student in Medicine, Harvard University. Address, 93 Boylston Street, Boston, Mass.

Arthur Henry Elliott, Ph.D., Anthony's Bulletin, 591 Broadway, New York City.

Howard Van Fleet Furman, E.M., Holden Smelting Co., Denver, Col.

William Tudor Griswold, C.E., U.S. Geological Survey, Hooe Building, Washington, D. C.

Frederick Adolph Hemmer, Jr., Ph.B. Address unknown.

Charles Breck Judd, E.M., United States Deputy Surveyor, care of Smith & Winsor, Lordsburg, New Mexico.

Daniel James Leary, C.E., E.M., Contracting Engineer Bridges and Docks. Address, 43 East Twenty-Fifth Street, New York City.

Clement Le Boutillier, Ph.B., Eliza Furnaces, Pittsburgh, Pa.

Augustus Damon Ledoux, Ph.B., Superintendent Guano Manufacturing Co., Orient, Long Island.

Willard Parker Little, E.M., Ph.B., Architect, Little & O'Connor, Fifth Avenue cor. Twenty-third Street, New York City.

Walter Monfort Meserole, C.E., Civil Engineer and Surveyor, Sheffield Avenue near Atlantic, East New York, L. I.

Percy Neymann, Ph.D., Chemist, Sherwin, Williams & Co., 100 Canal Street, Cleveland, Ohio.

Michael Joseph O'Connor, E.M., Ph.B., Architect, Little & O'Connor, Fifth Avenue cor. Twenty-third Street, New York City.

Thomas Devlin O'Connor, Ph.B. Address, 12 East Forty-Fourth Street, New York City.

Lucius Pitkin, A.B., Ph.B., Analytical and Consulting Chemist and Assayer, 138 Pearl Street, New York City.

George Sharp Raymer, A.B., E.M., Idaho Springs, Col. Address, 63 Seventh Avenue, Brooklyn, N. Y.

William Thomas Richmond, Ph.B., 68 Thomas Street, New York City.

Arthur Carr Roberts, E.M., 372 Broadway, New York City.

Charles Pike Sawyer, Ph.B., The *Evening Post*, New York City.

William Waldemar Share, Ph.D., Tutor in Physics, Columbia College. Address, 336 Navy Street, Brooklyn, N. Y.

Chandler Dannat Starr, C.E., 134 Second Avenue, New York City.

Thomas Beale Stearns, E.M., Mechanical and Mining Engineer, P.O. Box 1151, New York City; 3 and 4 Duff Block, Denver, Colorado.

Alfred Earnest Swain, E.M. Address, 902 Prospect Street, Cleveland, Ohio.

Edgar Granger Tuttle, E.M., Assistant Mining Engineer, Cambria Iron Co., Johnstown, Pa.

Alvan Howard Van Sinderen, Ph.B., Lawyer, 45 William Street, New York City. Residence, 178 Columbia Heights, Brooklyn, N. Y.

Hermann Theodore Vulté, Ph.D., Fellow in Chemistry. Assistant Instructor in Qualitative Analysis, School of Mines, Columbia College, New York City.

Ferdinand G. Wiechmann, Ph.D., Instructor in Chemical Philosophy and Chemical Physics, School of Mines, Columbia College, New York City.

William Fish Williams, E.M., C.E. Address, Box 33, Wethersfield, Conn.

Herbert M. Wilson, C.E., Topographer, U. S. Geological Survey, Washington, D. C.

1882.

Albert Calman, Ph.D., New York Glue Co., 215–219 Tuttle Avenue, Elmira, N. Y.

Thomas Peters Conant, E.M., Electrical Engineer, Electrical Accumulator Co., 44 Broadway, New York City.

William Hamilton Cooper, Ph.B.

Francis Bacon Crocker, E.M., Curtis & Crocker, 140 Nassau Street, New York City. Residence, 54 West Twenty-first Street, New York City.

Oscar Vincent Dougherty, Ph.B., with A. Dougherty, 80 Centre Street, New York City.

Stancliff Bazen Downes, C.E., Assistant Engineer, Department of Public Parks, Fifth Avenue and Sixty-fourth Street, New York City. Address, 1071 Madison Avenue.

William Fletcher Downs, E.M., Superintendent at Joseph Dixon Crucible Co., Jersey City, N. J. Residence, 75 Fairview Avenue.

Anton Frederick Emrich, E.M., Superintendent, Madonna Mine, Monarch, Col.

David Beauregard Falk, C.E. Address, care Falk & Co., 269 King Street, Charleston, S. C.

Henry Feuchtwanger, Ph.B. Address, 99 Franklin Street, Room 19, New York City.

Charles Lincoln Fitch, E.M., Superintendent San Pedro Mine, Montezuma County, Sonora, Mexico. Address, 124 W. 42d Street, New York City.

Charles Buxton Going, Ph.B., Porter & Going, Engineers and Chemists, Cincinnati, Ohio. Address, Glendale, Ohio.

William Hill, C.E., with Collins Co., P.O. Box 196 Collinsville, Conn.

William Charles Illig, E.M. Address, 327 East Forty-first Street, New York City.

Cavalier Hargrave Joüet, Ph.B., Chemist, G. H. Nichols & Co., Laurel Hill Chemical Works, L. I. Address, Roselle, N. J.

Antonia Esteban Mesa, C.E., Sagua la Grande, Cuba.

Alfred Joseph Moses, E.M., Instructor in Mineralogy and Metallurgy, School of Mines, Columbia College, New York City.

Edward Austin Oothout, E.M., care of Neftel & Oothout, 41 Liberty Street, New York City.

William Stevens Page, E.M., Aqueduct Commission, Sing Sing, N. Y.

William Barclay Parsons, Jr., A.B., C.E., Chief Engineer, Fort Worth & Rio Grande Railway, Texas. Residence, 505 Fifth Avenue, New York City.

Clarence Quintard Payne, E.M., Yale & Towne Manufacturing Co. Address Stamford, Conn.

John Bonsall Porter, E.M., Ph.D., Lecturer on Metallurgy, Cincinnati University. Address, Glendale, Ohio.

Cornelius Van Vorst Powers, Ph.B. Address, 22 West Forty-eighth Street, New York City.

Ferdinand Sands, A.B., Ph.B., Ripley Dry Plate Co., 32 Tiffany Place, Brooklyn, N. Y., Box 44, New Brighton, Staten Island.

Willard Adams Shumway, A.M., E.M., U. S. Geological Survey, Washington, D. C.

William Field Staunton, E.M., Tombstone Mill and Mining Co., Tombstone, Arizona.

Nathaniel Strange Stockwell, E.M., Patent Lawyer, care Briesens & Steele, 229 Broadway, New York City.

Donald Butler Toucey, E.M., Lawyer. Address, 43 West Fifty-third Street, New York City.

Frank Weiss Traphagen, Ph.D., Instructor in Chemistry and Physics, Staunton Male Academy, Staunton, Va.

Rudolph Harrison Vondy, E.M., Chemist, Phœnix Iron Works, Phœnixville, Pa.

John Howard Wainwright, Ph.B., Chemist, U. S. Laboratory, 402 Washington Street, New York City.

Albert George Wanier, Ph.B., care of Frederick Beck & Co., 206 West Twenty-ninth Street, New York City.

Norbert Reillieux Ward, E.M., 74 West Twenty-third Street, New York City, care James M. Stout.

William Scherf White, E.M., Surveyor and Draughtsman, 79 Cedar Street, New York City. Residence, 430 Gold Street, Brooklyn, N. Y.

William Alexander Wilson, E.M., Foreman, Marsac Mill, Park City, Utah.

Charles Augustus Wittmack, M.S., Ph.D., Chemist, care August Loss & Co., 26 and 28 Frankfort Street, New York City.

Edward Leavitt Young, E.M., New York Milling and Ore Testing Works, 528 West Sixteenth Street, New York City.

1883.

George Howard Abeel, E.M., Assistant Manager Iron Cliffs Mining Co., Negaunee, Marquette Co., Michigan.

Randolph Adams, E.M., Mill Superintendent Silver King Mining Co., Silver King, Pinal Co., Arizona.

Alberto Ayestas, Ph.B. Address, Tegucigalpa, Honduras, Central America.

Samuel Weed Balch, E.M., with E. E. Garvin & Co., Machinery. Address, P.O. Box 730, Yonkers, N. Y.

John Henry Banks, E.M., Chemist, with Professor Ricketts, School of Mines, New York City.

Alonzo Frink Bardwell, E.M., Assayer and Chemist, Box 773, Aspen, Pitkin County, Col.

Thomas John Brereton, A.B., C.E., Assistant Supervisor Monongahela Division, Pennsylvania R. R., Monongahela City, Pa.

†Henry Draper Brewster, 44 West 53d Street, New York City.

Charles Bullman, Ph.B., Chemist and Assayer, P.O. Box 1577, Plainfield, N. J.

Joseph Maxwell Carrere, C.E., Assistant Superintendent, Composite Iron Works Co., Long Island City. Address, P.O. Box 3273, New York City.

John Parke Channing, E.M., Exploring and County Surveyor, Bessemer, Gogebic, Michigan.

George Endicott, E M., Box 327 Sing Sing, N. Y.

Carlos Ferrer Ferrer, C.E., Engineer Corps, Aqueduct Commission, Morris Dock, New York City.

Junius Colton Ferris, E.M., care H. G. Ferris, Carthage, Ill.

Enrique Constantino Fiallos, C.E., Government Civil Engineer, Tegucigalpa, Honduras, Central America.

Dunbar Ferdinand Haasis, E.M., Assayer and Melter, Parral Mining and Milling Co., Parral, Mexico.

William Scott Humbert, E.M., Croton Aqueduct Engineer Corps, Division Engineers Office, Morris Dock, New York City.

Alfred Wipple Lilliendahl, E.M. Address, 82 Danforth Avenue, Jersey City, N. J.

John Joseph MacTeague, E.M. Address, P.O. Box 51, Laredo, Texas.

Charles Francis McKenna, Ph.B., 144 West Ninety-ninth Street, New York City.

James Guerrero Oxnard, Ph.B., Fulton Sugar Refinery, corner Dock and Water Streets, Brooklyn, N. Y.

George Edward Painter, Ph.B., care J. Painter & Sons, Pittsburgh, Pa.

Charles Frederic Paraga, C.E., 69 East Fifty-third Street, New York City. Address, care of D. de Castro & Co., 54 William Street, New York City.

Robert Peel, Jr., E.M., Bloomfield, N. J.

Frederick Powell, A.B., E.M., Central City, Gilpin County, Col.

Edmund Randolph, Ph.B., Secretary and Treasurer, Alabama Mineral Land Co., New York Office, 7 Nassau Street, New York City.

George Renault, C.E., 115 Broadway, New York City.

Jacob Monroe Rich, E.M., C.E. Address, 50 West Thirty-eighth Street, New York City.

John Clarence Richardson, E.M., C.E., 62 Nassau Street, New York City.

Thomas Weddle Ridsdale, E.M., 155 Gates Avenue, Brooklyn, N. Y.

George Augustus Suter, E.M., with N. Y. Exhaust Ventilator Co., 45 Fulton Street, New York City.

George Atwater Tibbals, C.E., Continental Iron Works, 148 Milton Street, Greenpoint, Long Island, N. Y.

Albert Edward Tower, E.M., Fallkill Iron Co., Poughkeepsie, N. Y.

---

† Associate Member. Not eligible for office.

Arthur Lucian Walker, E.M., Silver King Mining Co., Silver King, Arizona.
Walter Harvey Weed, E.M., Assistant Geologist, U. S. Geological Survey, Washington, D. C.

1884.

Herbert Clarendon Alden, E.M., Corps of Engineers, Aqueduct Commission, 269 West 125th Street, New York City.
William Crittendon Adams, C.E., 19 Park Place, New York City.
William Mood Baldwin, Ph.B., corner Green and West Streets, Brooklyn, E. D., N. Y.
Edward Chester Barnard, E.M., U. S. Geological Survey, Washington, D. C.
Edgar Grant Barratt, C.E., Exhaust Ventilator Company, 89 Madison Street, Chicago, Ill.
Oscar Bodelson, E.M., 1077 Tenth Avenue, New York City.
William Brice, Jr., Ph.B., 40 West Fifty-fourth Street, New York City.
John Rowlett Brinley, C.E., 322 Bellville Avenue, Newark, N. J.
Frederick Endicott Buckingham, E.M., Representative of the Am. Engineer, 80 Clifton Place, Brooklyn, N. Y.
Wilmot Woodward Burritt, Ph.B. Address, Tenafly, N. J.
John Thomas Corcoran, E.M., 131 Smith Street, Brooklyn, N. Y.
Francis B. Del Calvo, C.E., Spanish-American Light and Power Company, Havana, Cuba.
William Patterson Duncan, E.M. Address unknown.
Walter Lorton Dusenberry, E.M., Room 330, Produce Exchange, New York City.
Langdon Chevis Easton, C.E., Engineer Corps, Aqueduct Commission, P.O. Box 431, Sing Sing, N. Y.
George Ernest Fahys, C.E., care Jos. Fahys & Co., 38 Maiden Lane, New York City. Address 275 Clinton Avenue, Brooklyn, N. Y.
Josiah Huntingdon Fitch, E.M., 240 West Forty-third Street, New York City.
George Edward Fitzgerald, E.M., 214 Park Place, Brooklyn, N. Y.
Samuel Stewart Fowler, A.B., E.M., Assistant Superintendent Galena Reduction Works, Galena, Lawrence County, Dakota.
Charles G. Glover, E.M. Care of William M. Habishaw, 156 Front Street, New York City. Residence 125 Hall Street, Brooklyn, N. Y.
Edgar Bonaparte Gosling, E.M., 406 West Seventy-third Street, New York City.
Samuel Palmer Griffin, Jr., E.M., 50 West Ninth Street, New York City.
Louis Nathan Gross, B.S., E.M., 38 East Fifty-eighth Street, New York City.
James Thurston Horn, A.B., C.E., 13 East Fifty-third Street, New York City.
James Furman Kemp, A.B., E.M., Instructor in Geology, Cornell University, Ithaca, N. Y.
Andrew Johnson Lamb, E.M., Aqueduct Dept., Tarrytown, N. Y.; also 1328 Riggs Street, Washington, D. C.
Eberhard Luttgen, Ph.B., care Keasby & Mattison, Ambler, Pa.
John Wilkeson McGenniss, Jr., E.M., Room 408, First National Bank Building, Chicago, Ill.
Robert Albert McKim, C.E., 32 West Fifty-eighth Street, New York City.
Charles Swain McLoughlin, Ph.B., 2041 Fifth Avenue, New York City.
Charles Watts Miller, E.M., Lloyd & Miller, Mining Engineers, P. O. Box 401, Aspen, Pitkin County, Col.
Walter Moeller, Ph.B., 336 West 29th Street, New York City.

Daniel Edward Mo.an, C.E., with C. H. Delamater & Co., Thirteenth Street and North River. Residence, 85 State Street, Brooklyn, N. Y.

William Fellowes Morgan, A.B., E.M., Banker, 80 Broadway; 171 Madison Avenue, New York City.

Robert Mulford, E.M., Assistant Superintendent Rio del Oro Gold Company, Argentine Republic, S. A.; also Mt. Vernon, N. Y.

Arthur Howell Napier, E.M., 6 Strong Place, Brooklyn, N. Y.

Wolcott Ely Newberry, E.M., Superintendent Argentine Mining Company, Aspen, Col.

William Newbrough, A.B., E.M., 128 West Thirty-fourth Street, New York City.

Thomas Nolan, M.S., Ph.B., Architect, American Express Building, 107 State Street, Rochester, N. Y.

John Isaiah Northrop, E.M., 130 West Fifty-ninth Street, New York City.

Alvan Crocker Nye, Ph.B., Yonkers, N. Y.

Charles Albert Painter, E.M., care of J. Painter & Sons, Pittsburgh, Pa.

Charles Fowler Pearis, E.M., Assayer and Chemist, Helena Mining and Reduction Company, Wickes County, Montana.

Charles Ernest Pellew, E.M., School of Mines, Columbia College, New York City.

Abram Skidmore Post, C.E., Great Neck, L. I. Address, 173 Madison Avenue, New York City.

Lewis J. Powers, Jr., E.M., Springfield, Mass.

William Ross Proctor, E.M., Piitsburgh Club, Pittsburgh, Pa.

Daniel William Reckhart, E.M., Salt Lake, Utah.

Frederick Roeser, B.S., E.M., Assayer and Chemist to Mutual Smelting and Mining Company, Colville, Stevens County, Washington Ter.

Roland Gouverneur Rood, Ph.B., care Professor O. N. Rood, Columbia College, New York City.

Charles Bradley Rowland, C.E., with Continental Iron Works. Address, 329 Madison Avenue, New York City.

Philis Rupp, Jr., Ph.B., Student in Medicine, College of Physicians and Surgeons. Address, 182 E. Seventy-sixth Street, New York City.

Emanuel Schöney, E.M., Dept. of City Works, Brooklyn. Residence, 324 E. Seventy-second Street, New York City.

Frank Dempster Sherman, Ph.B., School of Mines.

Charles Goddard Slack, E.M., Assayer at the Virginius. Residence, 136 West Sixth Street, Leadville, Col.

Henry Ashton Smedberg, C.E., 347 Fifth Avenue, New York City.

Thomas Edward Snook, E.M., with J. B. Snook & Sons, Architects, 12 Chambers Street, New York City.

Clarence Livingston Speyers, Ph.B., 50 West Seventeenth Street, New York City.

Samuel Gaylord Tibbals, C.E., 148 Milton Street, Brooklyn, N. Y.

Beverly Reid Value, E.M., Engineer, Aqueduct Department, P. O. Box 175, Tarrytown, N. Y.

Frederick Kidder Walbridge, E.M., 71 Downing Street, Brooklyn, N. Y.

George Edward Wood, E.M., 37 West Fifty-fourth Street, New York City.

1885.

Ernest Julius Hyacinthe Amy, A.B., E.M., San Juan and New York Mining and Smelting Company, Durango, Col. Address, 18 West Twenty-seventh Street, New York City.

Howell Finch Barkley, E.M., Maysville, Ky.

Frederick Pomeroy Bemis, A.B., E.M., Bannack Hotel, Bannack, Montana. Lessee of Dakotah Mine.

Andrew Joseph Brennan, C.E., United States Coast Survey, Sandy Hook, N. J.

William Faulkner Bush, E.M., P. O. Box 225, Flushing, L. I.

George Carey, Ph.B., Delaware Avenue, Buffalo, N. Y.

Franklin Stanley Clark, E.M., Ph.D., Fernoline Chemical Company, Charleston, S. C.

Harmon Cozzens, E.M., 317 Lexington Avenue, New York City.

Charles Burton Crowell, Ph.B., 662 Prospect Street, Cleveland, Ohio.

Charles Henry Detwiller, Ph.B., 56 Danforth Avenue, Jersey City, N. J.

Charles Horace Doolittle, E.M., care John B. Fitch, P. O. Box 2070, Denver, Col.

Arthur Smith Dwight, E.M , Colorado Smelting Company, South Pueblo, Col.

Edward Crittenden Eddie, E.M., Colorado Smelting Company, South Pueblo, Col.

Eugene Nicholas Engelhardt, E.M., Assayer, P. O. Box 703, Pueblo Smelting and Refining Company, Pueblo, Col.

Charles Everett Graff, E.M., 601 Pavonia Avenue, Jersey City, N. J.

Burnham Hart, C.E., 687 Madison Street, Brooklyn, N. Y.

Emil MacDougall Hawkes, E.M., with Daily & Hoyt, Counsellors-at-Law, 44 Broadway, New York City. Residence, 267 Fifth Avenue.

Russell Wadsworth Hildreth, E.M., Union Bridge Works, Buffalo, N. Y.

Henry Leonard Hollis, E.M., North Chicago Rolling Mill Company, South Chicago, Ill.

Frederick Wolcott Huntington, E.M., Red Cliff, Eagle County, Col.

Edward Lovering Ingram, C.E., United States Engineer's Office, Wilmington, Del.

Arthur Gale Johnson, E.M., care of I. G. Johnson & Co., Spuyten Duyvil, N. Y.

Charles Frederick Lacombe, E.M., 121 Fifth Avenue, New York City.

George Barstow Lee, E.M., Assayer, Kansas City Smelting and Refining Company, P. O. Box 119, Argentine, Wyandotte County, Kansas.

Paul August Louis Mannheim, E.M. Address, 123 Clermont Avenue, Brooklyn, N. Y.

Leon Marié, E.M., 48 West Nineteenth Street, New York City.

Frederick James Hamilton Merrill, Ph.B., Fellow in Geology, School of Mines, Columbia College. Residence, 126 East Sixtieth Street, New York City.

Hermann Henry Bernard Meyer, E.M., Oregon Iron Works, 531–543 West Twentieth Street, New York City. Address, 162 Hayward Street, Brooklyn, N. Y.

Charles Lewis Miller, E.M., 106 Tenth Street, Brooklyn E. D., N. Y.

Richard George Gottlob Moldehnke, E.M., Ph.D., Honorary Fellow in Qualitative Analysis, School of Mines, Columbia College. Address, 124 East Forty-sixth Street, New York City.

Louis Spencer Noble, E.M., care of Iron Silver Mining Company, Leadville, Col.

Robert Van Arsdale Norris, E.M., Assistant Engineer Susquehanna Coal Company. Address, Lock Box 726, Wilkesbarre, Pa.

George Stevens Page, E.M., Black Diamond Steel Works, Pittsburgh, Pa. Address, Bushton Avenue.

Harry Nelson Pierce, E.M., Chicago, Ill.

Ysidoro Ygnacio Polledo, E.M., Dept. de Ingenieros, J. C. de Cárdenas y Túcaso, Cárdenas, Cuba.

Wilbur Edgerton Sanders, E.M., Helena, Montana.

Henry Brengle Shope, Ph.B., New Brighton, S. I.

Emil Starek, E.M., Cleveland, O.

Joseph Struthers, Jr., Ph.B., Fellow in Mineralogy, School of Mines, Columbia College, New York City. Residence, 624 East One Hundred and Thirty-sixth Street.

Frederick Makew Thomas, E.M., Skaneateles, N. Y.

Warren Harriott Titus, E.M., Assistant Sanitary Engineer, Board of Health. Residence, Whitestone, Queen's County, N. Y.

Edward Newenham Van Cortlandt, E.M., Silver King Mining Company, Silver King, Pinal County, Arizona.

Frederick Morgan Watson, E.M. Sombrerete Mining Company, Sombrerete, Zacatecas, Mexico.

Edmund Pineo Whitman, E.M., Station "M," New York City.

Ernest Abram Wiltsie, E.M., Poughkeepsie, N. Y.

Ira Harvey Woolson, E.M., Assistant in Drawing, School of Mines, Columbia College, New York City.

1886.

Emilio Agramonte, Jr., C.E., 118 East Seventeenth Street, New York City.

José Cæsar Agramonte, C.E., 316 West Sixtieth Street, New York City.

Henderson Moffet Bell, Jr., C.E., Staunton, Va.

John Dougherty Berry, E.M., Newman, Ga.

Wilton Guernsey Berry, Ph.B., Fréres Schlicher, Berlin, Germany.

Edward Pearce Casey, C.E., Resident Graduate, School of Mines, Columbia College, New York City.

Henry Dunning Conant, E.M., P. O. Box 1494, Orange, N. J.

Richard Mason Edwards, E.M., Houghton, Houghton County, Mich.

Emil Frankfield, C.E., 328 West Fifty-sixth Street, New York City.

William Dodge Horne, Ph.B., Fulton Sugar Refining Company, Dock and Water Streets, Brooklyn, N. Y.

George McClelland Houtz Good, E.M. Mining Engineer to Houtz Estate, Houtzdale, Clearfield Co., Pa. Address, Osceola Mills, Clearfield County, Pa.

Epenetus Howe, E.M., Princeton College, New Jersey.

John Howell Janeway, Jr., E.M., Governor's Island, New York Harbor.

Arthur Wilton Jenks, E.M., Address, care William R. Grace & Co., Hanover Square, New York City.

Henry Snyder Kissam, Ph.B., 145 West Forty-eighth Street, New York City.

Ernest Joseph Lederle, Ph.B., Stapleton, S. I.

Henry Charles Lee, C.E., 127 East Twenty-first Street, New York City.

Edgar Lieber Newhouse, E.M., Assayer for the Mexican Ore Company, Sierra Mojada, Coahiula, Mexico.

Lucien Holley Norton, E.C., Engineering Department N. Y., N. H. and H. R. R. Company. Residence, 123 Fairfield Avenue, Bridgeport, Conn.

James Jackson Ormsbee, E.M., Engineer Tennessee Coal and Iron Company, Tracy City, Grundy County, Tenn.

Theodore H. Osterheld, E.M., Yonkers, N. Y.

Staunton Bloodgood Peck, E.M., C.E., School of Mines, New York City.

Henry Hobart Porter, Jr., E.M., Fellow in Geology, School of Mines, Columbia College. Residence, 168 West Forty-seventh Street, New York City.

Augustus Meader Ryon, E.M., care F. N. Owen, 13 William Street, New York City.

Allen Newhall Spooner, C.E., 296 Ninth Street, Jersey City, N. J.

Robert Henry Stodder, E.M., Assayer for the Mexican Ore Company, El Paso, Texas.
William Henry Stuart, C.E.., 425 Clinton Avenue, Brooklyn, N. Y.
Henry Clark Thompson, C.E , Assistant Engineer Suburban Rapid Transit Company. Residence, 152 East One Hundred and Eleventh Street, New York City.
Arthur Hoffman Van Brunt, Ph.B , 27 West Thirtieth Street, New York City.
Ernest Robert Von Nardroff, E.M., 477 Carlton Avenue, Brooklyn, N. Y.
William Jefferson Wallace, Ph.B., Whitestone, L. I.
Joseph Yendes Wheatley, C.E., care of N. Y. C. and H. R. R.R., Grand Central Depot, Forty-second Street, New York City.
Clarence Edgar Wilson, Ph.B., Providence, R. I.

1887.

Walter Hull Aldridge, E.M., 217 Prospect Place, Brooklyn, N. Y.
Hiram Paulding Bellinger, C.E., 1157 Chestnut Street, Elizabeth, N J.
Joseph Rudolph Bien, *E.M.*, 139 Duane Street, New York City.
Abraham Lincoln Burns, E.M., 620 Greene Avenue, Brooklyn, N. Y.
Elmer Z. Burns, E.M., Pekin, N. Y.
William Curtis Butler, Met. Eng., 175 Division Street, Paterson, N. J.
Elihu Dwight Church, Jr., E.M., Post-Graduate. Address, 112 Milton Street, Brooklyn, N. Y.
Harold Morris Cole, E.M., 287 Third Street, Jersey City, N. J.
Ernest Arnold Congdon, Ph.B., Champlain Fibre Company, Willsborough, Essex County, N. Y.
Jennings Stockton Cox, Jr., Met. Eng., 2002 Fifth Avenue, New York City.
Harry Gilbert Darwin, C.E , Glen Ridge, N. J.
Charles Henry Davis, C.E., 576 Lexington Avenue, New York City.
Harry Ellingwood Donnell, Ph.B., 341 West 56th Street, New York City.
William Cashman Augustine Ferguson, Ph.B., 138 Wilson Street, Brooklyn, N. Y.
Samuel Edson Gage, Ph.B., Flushing, L. I.
Byron Benjamin Goldsmith, Ph.B., 19 E. 74th Street, New York City.
Edward Gudeman, Ph.B., Student at Berlin.
Alfred Maurice Heinshiemer, C.E., 344 East 50th Street, New York City.
Henry Ogden Huntting, Ph.B., 134 York Street, Jersey City, N. J.
David Mark Jacobs, Ph.B., 30 West 38th Street, New York City.
Solomon Joseph Jacobs, Ph.B., 30 West 38th Street, New York City.
Bernard John Theodore Jeup, C.E., 147 Luquer Street, Brooklyn, N. Y.
Joseph Lahey, E.M., 162 East 78th Street, New York City.
Richard Lahey, E.M., 162 East 78th Street, New York City.
Lea McIlvaine Luquer, C.E., Post-Graduate. Address, Bedford Station, N. Y.
Graham Lusk, Ph.B., 47 East 34th Street, New York City.
Harold Steele MacKaye, C.E., 172 Lexington Avenue, New York City.
Hermann Charles Munnheim, E.M., 123 Clermont Avenue, Brooklyn, N. Y.
John Rollin Marsh, E.M., Muncie, Ind.
John Middleton, C.E., 350 Clermont Avenue, Brooklyn, N. Y.
Rudolf Moeller, Ph.B., 336 West 29th Street, New York City.
George Müller, Ph.B., 125 Mercer Street, Jersey City, N. J.
Harry Parmelee Nichols, E.M., 9 West 21st Street, New York City.
José Alejandro Primelles, C.E., Puerto Principe, Cuba.

Camilo Claudio Restrepo, E.M. Care of D. Castro & Co., 54 William Street, New York City.

George Samuel Rice, Jr , E.M., 122 West 129th Street, New York City.

George Rowland, C.E., 329 Madison Avenue. New York City.

Lewis Hopkins Rutherfurd, E.M., "The Ariston," Broadway and 57th Street, New York City.

William Jay Schieffelin, Ph.B., 242 East 15th Street, New York City.

Joseph Guy Seligman, E.M., 21 East 76th Street, New York City.

Francis May Simonds, E.M., 147 East 34th Street, New York City

Richmond Edward Slade, Ph.B., Yonkers, N. Y.

Frank McMillan Stanton, E.M., 419 West 23d Street, New York City.

John Armitage Staunton, Jr., E.M., Syracuse, N. Y.

Alexander Stevens, C.E., Hoboken, N. J.

Frederic Wetherwax Tower, E.M., Post-Graduate. Address, 1836 Lexington Avenue, New York City.

George Francis Donnell Trask, E.M., New Brighton, S. I.

Walter Lincoln Tyler, C.E., 1314 Pacific Street, Brooklyn, N. Y.

Joseph Lowrey Warner, E.M., 26 East 22d Street, New York City.

Paul Oscar Wels, B.S., E.M., 10 East 112th Street, New York City.

ALPHABETICAL INDEX.

Abeel, '83
Adams, J. M., '67
Adams, R., '83
Adams, W. C., '84
Adams, W. I., '78
Agnew, Hon.
Agramonte, E., '86
Agramonte, J. C., '86
Alden, '84
Aldridge, '87
Allen, '74
Amy, '85
Andresen, '81
Aschman, '81
Austen, '72
Austin, '76
Ayestas, '83

Balch, '83
Baldwin, '84
Banks, '83
Bardwell, '83
Barkley, '85
Barnard, A. P., '68
Barnard, E. C., '84
Barnard, F. A. P., Hon.
Barratt, '84
Barros, '77
Barus, '77, Assoc.
Baxter, '68
Beard, '77
Beebe, '80
Behr, '77
Bell, '86
Bellinger, '87
Bemis, '85
Benedict, '74
Benjamin, F. P., '80
Benjamin, M., '78
Berry, J. D., '86
Berry, W. G., '86
Bien, '87
Bleecker, '81
*Blossom, '69
Blydenburgh, '78
Bodelson, '84
Bolton, '79
Booraem, '78
Braschi, '81
Brennan, '85
Brereton, '83
Brewster, '83, Assoc.
Brice, '84
Bridgham, '67
Brinckerhoff, '78
Brinley, '84
Britton, '79
Bronson, '67
Brown, '67
*Browning, F. D., '80
Browning, J. H. B., '80, Assoc.
Brownson, '67
Bruckman, '69
*Bruen, '76
Brugman, '80
Buckingham, '84
Buckley, '77
Bullman, '83
Burns, A. L., '87
Burns, E. Z., '87
Burritt, '84
Bush, '81
Butler, N., '80
Butler, W. C., '87
Butler, W. P., '78
Cady, '77
Calman, '82
Cameron, '74
Campbell, '69
Canfield, A. C., '77
Canfield, F. A., '73
Carrére, '83
Carson, '68
Cary, '85
Casey, '86
Cauldwell, '77
Chandler, Hon.
Channing, '83
Chazal, '81
Chester, '68
Church, E. D., '87
Church, J. A., '67
Churchill, '80
Clark, E. P., '80
Clark, F. S., '85
*Clark, H. G., '77
Cloud, '79
Colby, A. L., '81
Colby, C. E., '77
Cole, '87
Colton, '73
Conant, H. D., '86
Conant, T. P., '82
Congdon, '87
Constant, '77
Cooper, '82
Corcoran, '84
Cornell, '77
Cornwall, H. B., '67
Cornwall, H. C., '79
Coursen, '68
Cox, '87
Cozzens, '85

* Deceased.

Craven, '76
Crocker, '82
Crowell, '85
Curtis, '81
Cushman, '78

Darwin, '87
Davis, C. H., '87
Davis, J. W., '78
Delafield, '69, Assoc.
Del Calvo, '84
De Luze, '79
Detwiller, '85
Devereux, '78
Donnell, '87
Doolittle, '85
Dougherty, '82
Douglas, '81
Downes, '82
Downing, '78
Downs, '82
Drummond, '78
Duncan, '84
Dunham, '81
Dusenberry, '84
Dwight, '85

Easton, '84
Eastwick, '79
Eddie, '85
Edwards, '86
Egleston, Hon.
Elliot, '78
Elliott, A. H., '81
Elliott, William, '80
Emrich, '82
Endicott, '83
Engel, '80
Engelhardt, '85

Fahys, '84
Fales, '71
Falk, '82
Ferguson, '87
*Fernekes, '78
Ferrer, '83
Ferris, '83
Feuchtwanger, '82
Fialos, '83
Fish, Hon.
Fitch, C. L., '82
Fitch, J. H., '84
Fitzgerald, '84
Floyd, '77
Foote, '76
Fowler, '84
Francke, '80
Frankfield, '86
Furman, '81

Gage, '87
Garlichs, '80
Garrison, '76
Geer, '68
Giddings, '67
Glover, '84
Going, '82
Goldschmidt, '71
Goldsmith, '87
Good, '86
Gordon, '71
Gosling, '84
Gracie, '67
Graff, '85
Gratacap, '76
Greene, '80
Greenleaf, '80
Griffin, '84
Griswold, '81
Gross, '84
Gudeman, '87

Haas, '78
Haasis, '83
Haffen, '79
Haight, '70
Hale, '67
Hall, '76
Hallock, '80
Hamilton, '76
Hanna, '68
Harding, '67, Assoc.
Harker, '79
Harmer, '67
Hart, '85
Hasegawa, '78
Hathaway, '79
Hawkes, '85
Heath, '67
Heinsheimer, '87
*Helleberg, '77
Hemmer, '81
Hendricks, '80
Hildreth, R. W., '85
Hildreth, W. E., '77
Hill, '82
*Hodges, '78
Holbrook, '76
Holden, '78
Hollerith, '79
Hollick, '79
Hollis, H. L., '85
Hollis, W., '78
Hooker, '69
Hopke, '80
Horn, '84
Horne, '86
Howe, '86
Hoyt, '76
Hudson, '80
Humbert, '83
Hunt, '76
Huntington, C., '69, Assoc.
Huntington, F. W., '85
Huntting, '87
Hutton, '76

Ihlseng, A. O., '77
Ihlseng, M. C., '75
Iles, '75
Illig, '82
Ingersoll, '70
Ingram, '85
Irving, '69

Jackson, '75
Jacobs, D. M., '87
Jacobs, S. J., '87
Janeway, '86
Jenks, '86
*Jenney, F. B., '72
Jenney, W. P., '69
Jeup, '87
Johnson, A. G., '85

* Deceased.

Johnson, E. M., '78
Johnson, G. H., '78
Johnston, '79
Jordao, '77
Joüet, '82
Joy, '75
Judd, '81

Karr, '78
Kelly, '77
Kemp, '84
King, '76
Kissam, '86
Klepetko, '80
Knapp, '70
Koch, '79
Kunhardt, '80

Lacombe, '85
Lahey, J., '87
Lahey, R., '87
Lamb, '84
*Lamson, '75
Lawrence, '78
Leary, '81
Leavens, '75
Le Boutillier, '81
Lederle, '86
Ledoux, A. D., '81
Ledoux, A. R., '74, Assoc.
Lee, '85
Leggett, '79
Lilliendahl, '83
Lilienthal, '70
Lillie, '74
Lindsley, '70
Little, '81
Lord, '76
Love, '76
Ludlow, '79
Luquer, '87
Lusk, '87
Luttgen, '84
Lyman, '78

MacKaye, '87
Mackintosh, '77
*MacMartin, '68
MacTeague, '83
Macy, '75
Maghee, '76
Mannheim, H. C., '87
Mannheim, P. A. L., '85
Marié, '85
Marsh, C. W., '79
Marsh, J. R., '87
Martin, '77, Assoc.
Mathis, '79
Matsüi, '78
Mattison, '80
Mayer, '79
McCulloh, '78
McDowell, '72
McGennis, '84
McKenna, '83
McKim, '84
McLoughlin, '84
Meissner, '80
Melliss, '68, Assoc.
Merrill, '85
Merritt, '80
Merwin, '79
Mesa, '82
Meserole, '81
Meyer, '85
Middleton, '87
Miller, C. L., '85
Miller, C. W., '84
Miller, G. M., Hon.
Milliken, '79
Moeller, R., '87
Moeller, W., '84
Moffat, '68
Moldehnke, '85
Moran, '84
Morewood, G. B., '78
Morewood, H. F., '76
Morgan, '84
Morris, '78
Moses, '82
Mott, '73
Mulford, '84
Müller, '87
Munroe, H. S., '69
Munroe, O. M., '79
Munsell, '78
Murphy, H. M., '78
Murphy, J. G., '77
Murray, '74

Nambu, '78
Napier, '84
Navarro, '80
Neftel, '79
Nesmith, '79
Nettre, '69
Newberry, J. S., Hon.
Newberry, S. B., '78
Newberry, W. E., '84
Newbrough, '84
Newhouse, '86
*Newton, '69
Neymann, '81
Nichols, H. P., '87
Nichols, R., '77
Noble, C. M., '79
Noble, L. S., '85
Nolan, '84
Norris, D. H., '77
Norris, R. V. A., '85
Northrop, '84
Norton, '86
Noyes, J. A., '78
Noyes, W. S., '75
Nye, '84

O'Connor, M. J., '81
O'Connor, T. D., '81
O'Grady, '76
Okuma, '78
Olcott, '74
*Olmstead, '78
Oothout, '82
Ormsbee, '86
Osterheld, '86
Owen, '78
Oxnard, '83

Page, G. S., '85
Page, W. S., '82
Painter, C. A., '84
Painter, G. E., '83
Palmer, '78
Parker, A. McC., '80

* Deceased.

Parker, R. A., '78
Parks, '80
Parraga, '83
Parrott, '70
Parsons, G. H., '68
Parsons, W. B., '82
Payne, '82
Pazos, '78
Pearis, '84
Peck, S. B., '86
Peck, W. G., Hon.
Peele, '83
Pellew, '84
Pennington, '68, Assoc.
Perry, '78
Pfister, '75
Pierce, '85
Pistor, '68
Pitkin, '81
Platt, '68
Polledo, '85
Pool, '75
Porter, H. H., Jr., '86
Porter, J. B., '82
Post, '84
Potter, '69
Powell, '83
Powers, C. V. V., '82
Powers, L. J., '84
*Priest, '77
Primelles, '87
Proctor, '84
*Putnam, '75

Radford, '77
Randolph, E., '83
Randolph, J. C. F., '69
Randolph, J. Fitz, '76
Raymer, '81
Reckhart, '84
Reed, S. A., '77
Reed, W. B. S., '79
Rees, B. F., '74
Rees, J. K., '75
Renault, '83
Restrepo, '87
Rhodes, F. B. F., '74
Rhodes, R. D., '79
Rice, '87
Rich, '83
Richardson, '83
Richmond, '81
Ricketts, '71
Ridsdale, '83
Riggs, '71
Roberts, A. C., '81
Roberts, G. S., '71
Robertson, K., '68
Robertson, R. S., '71
Robinson, '80
Roeser, '84
Rogers, '77
Rolker, '75
Rood, O. N., Hon.
Rood, R. G., '84
Ross, '76
Rowland, C. B., '84
Rowland, G., '87
Rupp, '84
Russell, '75
Rutherford, '87
Rutherfurd, F. M., '79
Rutherfurd, L. M., Hon.
Ruttman, '80
Ryon, '86

Sage, '77
Sanders, '85
Sands, '82
Sawyer, '81
Schack, '68
Schermerhorn, '68
Schieffelin, '87
Schneider, '76
Schöney, '84
Seligman, '87
Share, '81
Sheldon, '79
Sherman, '84
Shope, '85
Shumway, '82
Simonds, '87
Singer, G., '80
Singer, G. H., '80
Slack, '84
Slade, '87
Sloane, '72
*Smalley, '80
Smeaton, '77
Smedberg, '84
Smith, L., '68
Smith, M., '80
Smith, W. A., '68
Smythe, '77
Snook, '84
Speyers, '84
Spooner, '86
Stallknecht, '68
Stanton, '87
Starek, '85
Starr, C. D., '81
Starr, H. F., '79
Staunton, J. A., Jr., '87
Staunton, W. F., '82
Stearns, '81
Stevens, '87
*Stewart, F. B., '79
Stewart, H., '75
Stockwell, '82
Stodder, '86
Stone, '79
Strieby, '78
Struthers, '85
Stuart, '86
Suter, '83
Suydam, '79
Swain, '81

Terhune, '70
Thacher, '77
Thompson, H. C., '86
Thompson M. S., '75
Tibbals, G. A., '83
Tibbals, S. G., '84
Tilden, '76
Titus, '85
Tonnelé, '80
Torrey, '80
Toucey, '82
Tower, A. E., '83
Tower, F. W., '87
Traphagen, '82
Trask, '87
Trowbridge, Hon.

* Deceased.

Tucker, '75
Tuttle, E. G., '81
Tuttle, W. W., '67
Tyler, '87

Value, '84
Van Amringe, Hon.
Van Arsdale, '68
Van Blarcom, '76
Van Boskerck, '77
Van Brunt, '86
Van Cortlandt, '85
Van Lennep, '67
Van Nardroff, '86
Van Sinderen, '81
Van Wagenen, '70
Vondy, '82
Vulté, '81

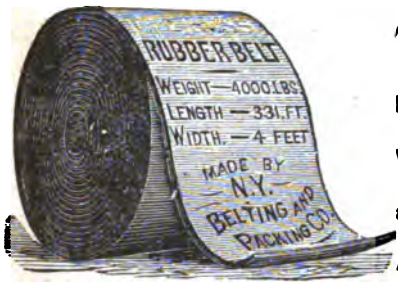
Wainwright, '82
Walbridge, A. C., '76
Walbridge, F. K., '84
Walker, A. L., '83
Walker, J., Jr., '80
Wallace, '86
Waller, '70
Wanier, '82
Ward, '82
Wardlaw, '76
Ware, Hon.
Warner, '87
Waterbury, '77
Watson, '85
Webb, '73
Weed, '83
Wells, '75
Wels, '87
Wendt, '72
Wetmore, '75
Wheatley, '86
Wheeler, H. A., '80
Wheeler, M. D., '68
White, '82
Whitman, '85
Wiechmann, '81
Williams, F. H., '74
Williams, G. W., '79
Williams, J. T., '73
Williams, W. F., '81
Willis, '78
Wilson, C. E., '86
Wilson, H. M., '81
Wilson, W. A., '82
Wiltsie, '85
Wittmack, '82
Wood, '84
Woolson, '85
Wright, '75

Young, '82

RUBBER BELTING, PACKING, HOSE,

RUBBER TUBING, RUBBER MATS,

MATTING, and STAIR TREADS.



All kinds of Rubber Goods for Mechanical Purposes.

DIAPHRAGMS, GASKETS and RINGS, ROLLS, STOPPLES, VALVES and TUBING—BLACK or WHITE, for GAS, WATER, and INSULATING RUBBER BAGS.

Largest Manufacturers in the U. S.

New York Belting and Packing Co.,

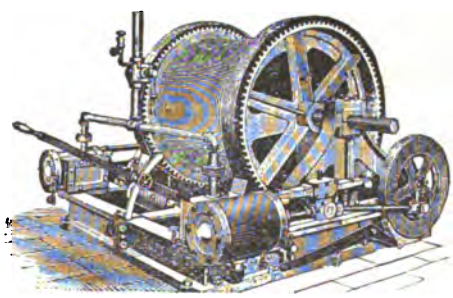
15 PARK ROW (Opposite Post Office), **NEW YORK.**

JOHN H. CHEEVER, TREASURER.

Improved Hoisting Engines

WITH

Wire-Rope Drums and Safety Brakes.



Specially adapted to Mining Interests.

ALSO COMBINED

Engines and Boilers, and Horizontal Stationary Engines.

LIDGERWOOD MFG. CO., 96 Liberty St., N. Y.

NEW CATALOGUES NOW READY.

WOODBRIDGE SCHOOL

(Late School of Mines Preparatory School)

No. 32 East Forty-Fifth Street,

NEW YORK.

Distinct Scientific and Classical Courses, introductory to all colleges; also Junior Department. The Scientific Course is carefully planned to be preparatory to the Columbia School of Mines.

INSTRUCTORS

PRINCIPAL:

J. WOODBRIDGE DAVIS, C. E., Ph.D.,
Mathematics, English.

ASSISTANTS:

PHILIPP J. J. VALENTINI, Ph.D.,
German Language.

APPLETON P. LYON, A.M.,
English and Classical Languages.

JOHN K. GORE, A.M.,
Mathematics, History.

FERDINAND G. WIECHMANN, Ph.D.,
Chemistry, Physics.

A. L. SEVESTRE,
French Language.

H. L. FAIRCHILD, B.S.,
Comparative Physiology, Geology.

HOBART B. JACOBS,
Drawing.

WILLARD H. POOLE, A.B.,
Latin, English Grammar.

SERIALS

The School of Mines Quarterly

vol. 8, 1886-87

DATE DUE | BORROWER'S NAME

D IN U. S. A.